INDIANA · STATE · SERIES

PRIMARY LESSONS IN HUMAN PHYSIOLOGY

Logansport Ind
Oct 28, 1897

Dear Minnie;—

Earth to earth
Dust to dust
If you don't love me
Somebody must.

Your beloved

Minnie:
Come and see me
when I get in
a house of my own
and I will do the
same with you
and Owen. Good Bye
your friend
Bessie

Remember me for
Bessie & Earl

Miss, Minnie Frye
Rock Creek
Ind, Carroll Co.
Bought Sep 29. 1897

MF

Owen Kirk,
Carroll,
Ind.

Minnie Frye
Logansport
Indiana

Oct 29, 1897
Little Rock Creek

Dear Winnie; —
Some loves one
Some loves two
I love one and
That is you.
Your sweet heart
For ever.

Remember me.
Sweet heart

Sugar lump
for get me not

INDIANA STATE SERIES

PRIMARY LESSONS

IN

HUMAN PHYSIOLOGY

BY

OLIVER P. JENKINS, PH.D.

PROFESSOR OF PHYSIOLOGY AND HISTOLOGY IN LELAND STANFORD JR. UNIVERSITY

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A WORD TO THE TEACHER.

THESE lessons have been prepared as a guide to the study of the human body; and while, no doubt, the teacher who undertakes to teach the subject of this little book is fully competent to do so, yet the writer may be pardoned for giving expression to his views in regard to the true place of such a book.

The writer would insist that the book be used only as a guide to such study and not the sole object to be studied. The human body itself should be the object studied. To supplement this, abundant materials from the bodies of lower animals should be used as a means to give true conceptions of the parts of the human body and its actions. If the teacher had sufficient time to give complete individual direction, a book would be of questionable use in this connection.

If this or any other elementary text-book in physiology is used simply as a book to be learned and recited, the time spent on it is worse than wasted. The terms used in the description of the parts of the body and their actions can not have their proper meanings unless the real objects are seen. To attempt to cram children's minds with terms which to them stand either for nothing, or for vague conceptions wholly different from those for which the terms have been chosen, is doing the children a great injury.

This procedure is not only harmful but unnecessary. Many of the parts of the body can be put under study and their operations carefully observed and analyzed. The lower animals can furnish the rest of the illustrations. A bone is a bone, the animal kingdom through. The same may be said for muscles, tendons, ligaments, nerves, and all other parts that make up the body.

Charts and drawings have also their place in teaching, but they should come after the objects, and never before, and cer-

tainly should not stand for them. If the charts and models prevent finding true m⁻terials for illustration, they have done harm.

The illustrations from the lower animals need have nothing unpleasant about them, and certainly nothing disgusting about them.

The subjects treated of in this book can all be illustrated by the bodies of some small animal, the dissection of which, if neatly done, will not disgust any one.

A chicken or a frog will answer admirably, and certainly its preparation for class study need be no more objectionable than its preparation for dinner.

The human body and the bodies of the lower animals should also be studied in action, each in its own natural surrounding, as organisms adapted to these surroundings. It is only by constantly seeing the organisms in their true relations to other things that even elementary conceptions of physiological facts can be obtained.

The teacher need not feel discouraged if not provided with charts or other apparatus, he can make use of the living world around him to illustrate the study of the most interesting of living organisms. The work thus pursued will be of a real value beyond the interesting knowledge gained, and will bring the reward of a satisfaction of having accomplished something of worth.

In the second book of this series the writer has introduced directions for the practical demonstration of many anatomical and physiological facts, which might well be suggestive to the teacher of this book. For these directions and for a fuller discussion of many of the subjects treated here reference may be made to the second book. There are now published many hand-books for the dissection of many of the groups of the lower animals, any one of which will be helpful in preparing illustrations for the study of the human body.

But illustrations of the work, or subjects for study, will be numerous enough and more vital if they come from his own observation and experience with the objects of study.

O. P. JENKINS.

GREENCASTLE, INDIANA,
May, 1891.

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PRIMARY PHYSIOLOGY.

CHAPTER I.

HOW MOTIONS IN THE BODY ARE PRODUCED.

The Study of the Human Body.—The human body is made up of a great number of parts, which may be called so many pieces of machinery. They work together so harmoniously that they all help each other. When, for example, a boy climbs a tree, almost every part of his body is contributing to this action. Many parts of his arms, his legs, the muscles and bones of the rest of the body, the eye, the touch organs, the nerves, the lungs, the heart, and indeed almost all the organs must act together to get the boy's body up the tree.

To study out how these actions are performed, and how such a large number of separate parts come to be so well controlled as to accomplish any thing the body can do, is well worth the trouble it takes. To understand more clearly the parts of the wonderful machine which is our constant servant, and to learn how to keep it in the best order, is certainly very important knowledge.

Study of the Hand and Arm.—One may well

begin the study of the human body by observing the common movements of his own arm and hand. Let him pick up an object from the table and raise it toward his mouth, and observe closely what takes place. First, the arm is straightened—that is, the part below the elbow, the fore-arm, is carried away from the part above. The whole arm may also be moved away from the body. The hand is carried toward the object, and just as it reaches it, the fingers and thumb are stretched out. The thumb and one or more fingers close together over the object to hold it firmly, when the fore-arm is carried toward the upper arm, and the hand with the object is carried toward the mouth. This is a very common action, and is repeated here to observe just what happens. Let us look at the actions separately, and attempt to see how they are accomplished.

Let us first examine the fingers and the thumb, and their actions. It is easy to determine that each finger has running through its central portion a row of three hard pieces, which are known well enough to be bones. These bones form two joints in the fingers, and the one next to the hand forms a joint with another bone at the knuckle. These joints allow the fingers to fold toward the palm of the hand, and to unfold again until straight, or even curved slightly backward. It is plain that if it were not for the rigid parts and the joints the fingers could not be extended with much force.

Now let us examine what is the action by which the bones of the finger are bent or straightened. If, while one is moving the fore-finger rapidly by ex-

tending and bending it, he places the finger of the other hand on the back of the hand just back of the moving finger, he can detect a firm cord crossing the knuckle and running toward the wrist. This becomes rigid every time the finger is extended. By causing each of the other fingers to move in the same manner, a similar cord for each one can be felt just under the skin. These cords can be traced even past the wrist into the fore-arm, where they are lost to the touch.

The skin of the palm is thicker than that on the back of the hand, so it is more difficult to detect the cords running from the palm side of the fingers at this place. But if we examine the region of the palm side of the fore-arm just above the wrist while the fingers are in motion, it is easy to show that there is a number of cords here which are moved every time the fingers are bent.

It is plain from this that the fingers are moved backward and forward by these strings pulling, first the one set, then the other. What pulls on the strings? If while the thumb and finger are closed and opened, as before observed, the other hand be made to grasp around the fore-arm just below the elbow, it will be found that this part of the arm shows great activity beneath the skin. This is due to the action of the parts that pull on the cords. These parts are the *muscles*. The cords are the *tendons*.

What the Muscles are like.—Not only are the fingers extended and bent by muscles pulling on the tendons which are tied to the finger bones, but when the arm is bent at the elbow, the action is accom-

plished by a muscle in the upper arm pulling on a tendon attached to a long bone in the fore-arm.

Fig. 1.

BICEPS MUSCLE ATTACHED TO THE RADIUS.

If with your left hand you grasp the right upper arm while the arm is being bent, the flesh on the front side of the arm will be felt to swell up greatly.

If the fingers be held at the front side of the elbow while the arm is being bent, a very large cord, the tendon, can be felt. The swelling flesh is a large muscle. Fig. 1 shows the arm with all the parts removed except the bones of the arm and this muscle and its tendons which bend the arm. Fig. 2 shows the same muscle removed, so as to better show its appearance.

Fig. 2.

BICEPS.

Appearance of a Muscle.—As seen in the figure, this muscle, which is called the *biceps*, has a thick body, tapering off at each end to the *tendons*. The thick body is composed of a reddish mass. The lean part of the flesh of an animal, which is familiar to every one, is muscle.

The muscle is surrounded by a tough membrane, which holds all of its parts together, and runs off toward the ends of the mus-

cle and continues into the tendon. The tendon runs to the bone, where it is continuous with a membranous covering of the bone. Thus the muscle comes to be firmly attached to the bone.

Action of the Muscle.—It has already been seen that when the hand clasps the arm over the *biceps* muscle during the bending of the arm, it is felt to swell up to a considerable thickness. If, when the muscle is in action, it could be examined with the covering of the arm removed, one could see it shorten as well as thicken. It is this power of shortening and thickening, or *contracting*, as it is called, which enables the muscle to pull the bone and cause the motion of the arm.

The cause of the motions of the fingers which we observed is also the *contraction of the muscles*. In the part of the arm just below the elbow is a number of muscles. Each one is smaller than the biceps, but it is shaped very much like it. Each one ends in a tendon at each extremity, the one toward the elbow being short and attached to some one of the bones at points near the elbow joint. At the end toward the hand the tendons are long, some passing to the wrist, some to the hand, but most of them passing on to the different joints of the fingers. Some run along the back of the hand, as we observed, and some on the palm side.

A Review of these Points.—To bend a finger, we contract a muscle in the fore-arm; to straighten it, we contract another. To straighten more than one finger, as in reaching for an object, we contract several muscles in the fore-arm; to bring them together

on the object, we contract several others in the same position. To bend the arm at the elbow, we contract the biceps. We may, by clasping the upper arm, find that when we straighten the arm, muscles on the opposite side from the biceps contract and pull on tendons attached to the fore-arm, and bring it back to its extended position.

Muscles that produce other Motions of the Arm.—If one place his hand at different positions around his shoulder while he lifts his whole arm up, brings it forward, backward, downward, or in any other direction, he will find that the muscles of the breast, of the top of the shoulder, or of the back, or just below the shoulder, are acting. These muscles are very large and make up most of the flesh in these regions. Those parts which lie just beneath the skin are shown in Fig. 3, but still others lie beneath these.

Other Muscles in the Body.—Whenever any motion of the parts of the body is made, it is by the contraction of the muscles. To produce the very many motions that the body performs, it is furnished with about five hundred muscles. Figs. 3 and 4 show where many of these muscles are placed, but a very large number lie deeper than these and many are small, so that all can not be represented at once.

Number of Motions.—The five hundred muscles can produce more than five hundred motions, for each one can produce a motion acting alone, a still different one when acting with another muscle, or even with several other muscles. For example, we may carry the whole arm in many hundreds of dif-

ferent positions with but a limited number of muscles, by combining their contractions in different ways.

Contractile Power of Muscles.—*The power of contractility* which the living muscle has is the source of the force which the body can exert. The contractile muscular substance is to the machinery of the human body what the steam is to the engine. It is well known that hot steam presses against the walls of the vessels containing it. It will lift the lid of a kettle, or may push so hard as to burst the walls of a steam-boiler. Men take advantage of this great power, and let the steam push against a piston, and by its connections turn a crank which makes all the motions in a great machine-shop.

In the body, the muscular substance, instead of pushing, as does steam, pulls on the ends of the vessels which contain it, and thus, by means of strings (tendons), pulls on the bones and makes the motions of the body.

Muscles in the Lower Animals.—The muscles in the common animals, such as horses, dogs, cats, rabbits, and the like, are of the same form, and are attached to bones in the same way as those in man. They have the same power of contracting and are in every respect like those of the human body.

The motions of all animals, except certain forms, chiefly microscopic, are produced by muscles. The muscles of the higher animals are arranged in about the same number and order on the limbs and the remainder of the body as in man. The examination of the muscles of the body of some small animal

would teach very clearly how the muscles appear and how they are arranged in man, and how the tendons attach them to the bones.

What causes the Muscles to Contract.—We know that we can cause the muscles to contract whenever we wish to do so. The arm can be moved at the exact moment and with just the force we desire. It is said, for example, that the muscles of the arm are under the control of the will. If the arm could be laid open for examination, there could be seen some other things beside muscles and tendons.

Among these latter would be seen some white cords, which divide into many branches, one going to each muscle. They penetrate the sheath of the muscle and are lost in its substance. These cords, dividing up into fine threads, are *nerves*. If they are traced from the muscles, they are found to run up the arm, through the shoulder, across to the backbone, and into its center. Here they connect with a large nerve cord, the spinal cord, which runs to the brain. These we will study later, but mention them here to show that the muscles are connected with the brain, through which the *will* acts.

Now, if a nerve going to a muscle be cut in two, then no power of the will can make it contract. It is only when the nerve connects the muscle with the brain that we can move the muscle when we wish. The brain can send some influence that the nerve is able to conduct, which, when it reaches the muscle substance, makes it contract. The exact nature of this influence is unknown, nor is it known how it

Fig. 4

BACK VIEW OF THE SUPERFICIAL MUSCLES OF THE BODY.

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makes the muscle contract. This influence is called a *nervous impulse.*

When a nervous impulse comes to a muscle to contract it, it is said to *stimulate* the muscle. Other things will stimulate a muscle to contraction beside the nervous impulse. For example, if a living muscle is touched with a hot wire, or pinched, or struck, or has applied to it some chemical substance or electricity, it will contract; but in the bodies of men and the lower animals only the nervous impulse is made use of to move the muscles.

Voluntary and Involuntary Muscles.—All those muscles whose action may be controlled by the will are called *voluntary* muscles. They are the great majority of the muscles in the body. The muscles of the heart and of the stomach, and of some of the other organs, are stimulated to action from some other source than the *will*, and the will can not control them. Consequently, they are called *involuntary* muscles.

Some of the most important actions of the body, such as those in the circulation of the blood, in breathing, and in the digestion of food, are carried on by involuntary muscles. The arrangement by which certain muscles may act independently of our care and attention allows important actions to go on while we are asleep, and when the mind is so occupied that they would be forgotten or neglected.

Further, these operations are so complex, and make use of processes that we know so little of, that, if they depended on our will alone for direction and control, they would surely go wrong in a very

short time. The involuntary muscles relieve us of the responsibility and trouble of these operations, and give us time to accomplish other motions.

Questions for Review.

1. What makes up the body?
2. How do the parts work in any action?
3. Show what is meant by the eye and foot working in harmony.
4. What takes place in the arm and hand in picking up some thing from the table?
5. What forms the hard parts of the fingers?
6. What are found fastened to them?
7. Describe the action of the joints.
8. Describe the course of the strings which are attached to the bones of the fingers.
9. What are these cords called?
10. What pull on them?
11. Describe a muscle.
12. How does a muscle act?
13. Where are the muscles that move the fingers?
14. Where are the muscles which extend the arm?
15. Where the muscles that bend the arm?
16. Where are their tendons?
17. Show in your own hand and arm all these parts.
18. Where are the muscles that lift, lower, and produce other motions of the whole arm?
19. Point out these muscles in Figs. 3 and 4.
20. How many muscles are there in the body?
21. Where are they placed?

22. What of the number of motions which they can produce?

23. How can two muscles produce more than two motions?

24. What is the source of the force which produces the motions of the body?

25. How may muscle substance be compared to steam?

26. What of the muscles in the lower animals?

27. What are the nerves?

28. With what do they connect the muscles?

29. What makes the muscles contract?

30. How do we know that a nervous impulse passes along a nerve?

31. What is meant by *stimulate?*

32. What are voluntary and what are involuntary muscles? Give examples.

33. What advantage is gained by having certain muscles act involuntarily?

CHAPTER II.

SKELETON OF THE UPPER EXTREMITIES.

General View.—Since the bones of the arm and hand are so easily traced, and their uses can be so clearly made out, we will study them in some detail. The bones of the arm illustrate many facts about bones in general. They are generally grouped as bones of the *hand*, the *fore-arm*, and the *arm*, and are attached to the body by the *shoulder girdle*, the whole group being sometimes referred to as the bones of the upper extremities.

The Bones of the Hand.—We have just seen that the fingers have each three bones and the thumb has two—fourteen in all. They are called the *phalanges*, a single one a phalanx. The five bones which we traced in the palm of the hand, and whose outer ends are the knuckles, are called the *metacarpals*.

Notice that the metacarpal of the thumb is free to move in many directions, while those of the fingers are firmly bound together. This arrangement allows the thumb to be brought opposite to any one of the fingers or to most points on the palm. This power of moving the thumb so freely increases very greatly the usefulness of the hand.

To convince one's self of this, let him attempt to use the hand without using the thumb in picking up

objects, and in handling them, and then in contrast repeat the operations with the help of the thumb. While the fingers without the thumb may become very expert, yet the thumb wonderfully increases the usefulness of the whole hand.

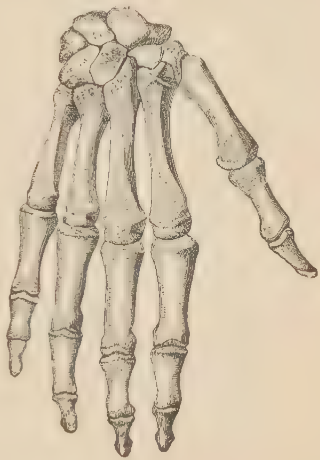

Fig. 5.

Bones of the Hand.

If we attempt to trace the metacarpals back toward the arm by feeling them under the skin, we soon lose them in the flesh that surrounds them.

Immediately under the skin and flesh in the wrist we can feel a solid portion. This is a bunch of small bones, eight in number, arranged in two rows of four in each row. They are the bones of the wrist and are called the *carpals.* Compare your own hand with the picture of the bones of the hand shown in Fig. 5.

Bones of the Fore-arm.—That part of the arm between the wrist and the elbow joint is called the fore-arm. Immediately back of the wrist joint the ends of the two bones may be felt under the skin. The end of one makes the little round knob which shows under the skin on the little-finger side of the arm.

This is the end of the *ulna.* The bone may be traced for its whole length, when it will be found to

extend to the elbow joint. It makes the point of the elbow where it is very close to the skin.

By the side of this bony knob of the ulna, near the wrist, lies the end of the *radius*. The broad end of this bone fills up the space from the knob of the ulna to the edge of the arm on the thumb side.

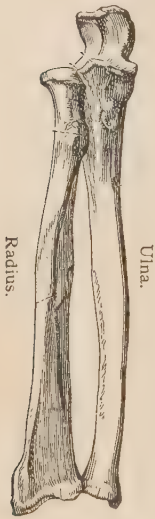

Fig. 6.

BONES OF THE FORE-ARM.

It is this broad end of the radius to which the hand is joined to make up the wrist joint. Thus the radius carries the hand. The radius may also be traced to the elbow joint.

Movements of the Radius.—If the hand be held out with the palm turned upward, it will be found that the radius and ulna lie side by side. Now, while the arm is in this position, turn the hand over, so as to bring the palm down, and during this motion watch the motion of the two bones of the fore-arm. It will be seen that the radius turns over the ulna until it comes to lie across it.

It ends at the elbow in a little shallow cup about three fourths of an inch across, which fits on a knob on the large bone of the arm. This cup-shaped end of the radius allows it to turn on this knob as on a point.

A groove in the side of the wrist end of the bone allows it to slide over the knob of the ulna. Now, muscles are so arranged that they can quickly pull

the radius over the rigid ulna; and as the radius carries the hand, of course the hand is turned over. This arrangement is for turning the hand over.

The same bones in a dog's fore-leg are bound firmly together, and, consequently, it can not turn its fore-paw over; but in the cat's fore-leg the radius has a little motion, and it may be seen while the kitten is playing with a ball, it will often turn its fore-paw slightly.

Now examine carefully the figures of the ulna and radius given here, and determine which parts of them you can make out in your own arm. It may be remembered from the lesson on muscles that it is to the radius that the biceps muscle is attached.

The Humerus.—In the part of the arm between the elbow and the shoulder is a very large bone called the *humerus*. A picture of this bone is shown in Fig. 7.

Fig. 7.

THE HUMERUS.

The elbow end has grooves and a knob for the ulna and radius to fit into. The shoulder end is formed into one large, smooth, round end to fit into a cup-shaped part of a bone at the shoulder, called the shoulder blade.

The sides of the broad end of the humerus are very prominent at the elbow, but the shoulder end, called the head of the humerus, is so deeply buried in the large muscles which move the arm that it can not be so well examined.

Scapula and Clavicle.—As was said, the round head of the humerus is fitted to a part of the shoulder blade, the *scapula* (seen in Fig. 8). One can not well make out the whole outline of this bone in his own shoulder, but he may easily trace it in that of another person.

Fig. 8.

THE SCAPULA.

The prominent hard part felt just at the top of the shoulder is the upper end of the ridge which runs across the bone. This ridge lies near the skin, and can be traced across the bone to its posterior edge, where it ends. The edges of the scapula can also be made out. It is a flat, triangular bone fitted to the upper part of the back. Besides acting as a support to the humerus, it serves also as a place to which are fastened many of the muscles that move the arm.

The *clavicle* is the collar bone. It is very near the skin at the front part of the base of the neck, and can be traced from the shoulder to a point at the top of the front part of the chest. Its use is to hold the shoulders and arms back from the chest.

The Pectoral Arch.—The clavicle and scapula together make a firm brace to support the arm and attach it to the body.

Often the arm is called upon to lift a heavy weight,

or push with great force against an object. These actions would be impossible if the arm were not thoroughly braced against the body. The scapula and clavicle make this brace, and are called the *pectoral arch*, or *pectoral girdle.*

Levers.—If at your desk you use a lead pencil to pry up one book by letting the side of the pencil rest on another, the lead pencil is used as a *lever.*

In the lever three points are named: the point to which the weight is attached, generally called *W;* the point to which the power is applied to lift the weight, called *P;* and the point where the lever is supported, called the fulcrum, whose sign is *F.* The point *F* is stationary, while the remainder of the lever turns on this.

Now, in the use of the pencil described, the point *F* was between *P* and *W.* When a lever is used in this way it is said to be a lever of the *first class.*

Now push one end of the pencil under one of the books for a short distance, and raise the other end of the pencil. It will be seen that now *F* is at one end of the pencil, while *W* is between *P* and *F.* The pencil so used is called a lever of the *second class.*

Now hold one end of the pencil down on the table, and after placing a book across the other end, raise the book by grasping some point on the middle portion of the pencil. In this case note that the point *P* is between *W* and *F.* The pencil so used is a lever of the *third class.*

The Rule of Levers.—In all of these cases the power required to lift the weight will be as much less or greater than the weight as the distance of

the weight from the fulcrum is less or greater than the distance of the power from the fulcrum. This is expressed in the following proportion: $P : W :: WF : PF$.

By levers of the first and second classes one can lift stones heavier than he is able to lift without them; but with a lever of the third class, since the weight and fulcrum are separated by the whole length of the lever, the weight lifted will always be less than the power required to lift it.

In regard to the velocity of the motion, the case is reversed. Whenever a lever gains an advantage in the amount of weight lifted, it loses proportionately in the velocity of the motion of the weight, and where it loses in the amount of weight, it gains in velocity.

Verification of these Rules.—These facts can be made very clear by using a rod of wood of two or three feet in length, measured off in inches. Known weights may be used as weights, and the lifting power of the hand may be measured by a spring balance placed between the hand and the lever.

The Bones of the Arm as Levers.—In applying our knowledge of levers to the action of the bones of the arm, we learn that when the biceps acts on the radius, it uses the bones bound together as a lever of the third class.

The tendon of the muscle is attached very near the fulcrum of the lever, which is in this case at the elbow, while the weight at the hand is at a much greater distance. In order to lift a weight of ten pounds in the hand, the muscle will have to exert

a force which, applied directly, would raise sixty pounds, but with the advantage of lifting the ten pounds with six times the velocity of the sixty pounds.

Each one of the phalanges, the hand used as a whole, and the humerus, are all levers of the third class.

The Uses of the Bones of the Arm and Hand.—Our study of the arm has shown that the uses of the bones of the arm and hand are three:

1. To act as levers.
2. To serve as fulcrums.
3. To furnish places for the attachment of muscles.

Each of these uses is concerned with the movements of the arm.

The Fore-limbs of the Lower Animals.—The bones of the fore-limbs of animals which have backbones—that is, mammals, birds, reptiles, frogs, and fishes—correspond to those of our own arm and hand.

The bones in the fore-leg of a cat are very much like our own. The clavicle is very small, and there are but seven carpals; otherwise they are all present, and of nearly the same shape.

As different as the fore-leg of a horse or of a cow appears from our own arm and hand, a comparison of the bones of each would show them to be remarkably alike.

The wrist bones of these animals are at the joint usually known as the "knee." The hand is very narrow, consisting of but one strong bone and two slender rudiments of bones to represent the metacarpals, and with but one finger in the horse, and

four fingers in the cow—two being fully developed, and two only rudiments.

Of course, we call these the feet of these animals, but they correspond exactly to the last joint of our fingers, the hoofs being the nails.

The fore-limbs of animals differ greatly in order to fit them to the different conditions of life in which we find them. If you will examine why this is true in the case of several animals, such as those just mentioned, and also of others, such as a bird, a mole, a squirrel, a rabbit, a sunfish, or a frog, the study will make the knowledge of our own arm much clearer.

Questions for Review.

1. What are the bones of the hand?

2. Point out each in your own hand.

3. How do those of the thumb differ from those of the finger?

4. Show what advantages are gained by having the thumb attached as it is.

5. Trace the outline of the bones of the fore-arm.

6. To which is the wrist attached?

7. Which one makes the point of the elbow?

8. How does the radius join the humerus?

9. Describe the action of the two bones in turning the hand over.

10. Does the knob at the wrist end of the ulna move in this action, or remain stationary?

11. How does the radius act in some of the lower animals?

12. Show all these points in the figures of the ulna and radius given in this book.

13. Give the position of the humerus and describe its form.

14. How do its two ends differ?

15. To what is each attached?

16. Describe the scapula and give its uses.

17. Locate the clavicle and state its use.

18. What is meant by the pectoral arch?

19. Explain the important use of the arch.

20. Show with a pencil and books (or with similar objects) what is meant by a lever.

21. Define the terms *power*, *weight*, and *fulcrum*.

22. Arrange the levers as one of the first, one of the second, and as one of the third class.

23. What is the rule for the levers in regard to the relation of the amount of power to the weight?

24. What is the rule in regard to the velocity of each, the weight and power?

25. Name each bone of the whole arm and show for each case: 1st, whether it is used as a lever; and 2d, of what class.

26. What are the advantages and disadvantages gained in the arrangement of the biceps muscles and the radius?

27. What are the uses of the bones of the arm?

28. How do the bones of the arm compare with those of the fore-limb of the lower animals?

29. Compare the bones of the human arm with those of the fore-leg of a cow or horse.

30. Show how the fore-limbs of several different animals are adapted to the actions they perform.

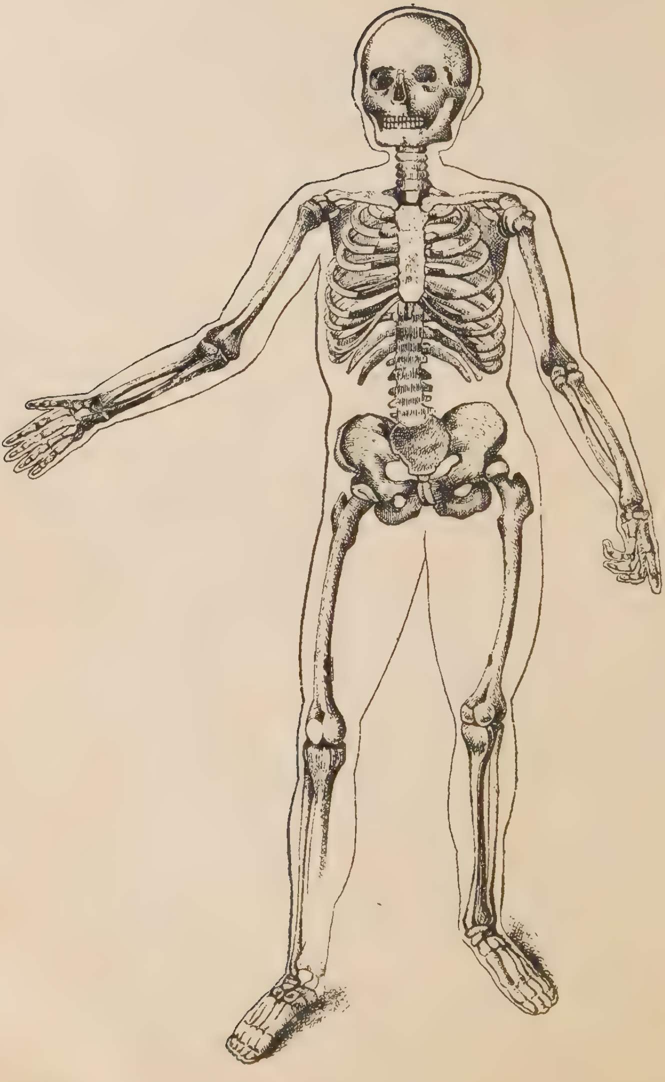

Fig. 9.

THE SKELETON.

CHAPTER III.

THE SKELETON.

The Bones of the Leg.—The bones of the leg correspond very nearly to those of the arm. In the toes the number is the same, and they are called by the same name, the *phalanges*. There are five *metatarsals*, in place of the metacarpals, and seven *tarsals* in the instep, which corresponds with the wrist.

The tarsals are of larger size than the carpals, while the phalanges of the foot are smaller than those of the hand. In Fig. 10 the bones of the foot are shown as sawed through. This shows the large tarsal which makes the heel bone.

Just above this bone is the next largest tarsal, which forms a joint with the bone of the lower part of the leg. In this figure we may see also how the tarsals with the metatarsals form an arch of bones on which the weight of the body rests in standing.

The large bone of the lower leg resting on the tarsal bone is the *tibia*. It extends from the instep to the knee, where, with the bone above, it forms the knee joint. By the side of the tibia lies the *fibula*, a long, slender bone firmly attached to the tibia.

The bone in the thigh is the *femur*. It is the largest bone in the body. The end at the knee is

broad and has a deep groove in it, while at the upper part there is a turn in the bone which then ends in a smooth ball.

This ball of the femur fits closely into a cup-shaped surface on the hip bone, to make the hip joint. The hip bone, or *os innominatum*, as it is named, is a large, irregularly shaped bone. It comes out from the central line of the body, its posterior edge joining firmly to the backbone, and the front edge being also

Fig. 10.

SECTION THROUGH THE BONES AND LIGAMENTS OF THE FOOT. THE PARTS OF THE JOINTS ARE WELL SHOWN.

firmly joined to the corresponding edge of the hip bone of the opposite side. Thus we see that the hip bone acts as a strong brace on the arch for the femur to press against, which bears to it the same relation as the pectoral arch does to the humerus. The hip bone makes the *pelvic arch*, or *pelvic girdle*.

The pelvic arch is a stronger one than the pectoral arch, as it must, during walking, bear the whole weight of the body, and often very heavy weights besides, which one may carry. If the leg be straightened, there can be easily detected at the knee a disk-

shaped bone which is known as the *patella*, or knee-cap.

This bone is imbedded in a large tendon which passes over the knee to join the tibia. The patella, by fitting into a groove on the end of the femur, helps the tendon work over the bend of the knee.

Fig. 11.
MUSCLES AND TENDONS OF THE BACK PART OF THE LEG.

Uses of the Bones of the Leg.—The bones of the leg are, like the bones of the arm, mostly used as levers. When the muscles of the front part of the thigh contract, they pull upon the tibia and extend the leg; when those on the opposite side contract, they bend the leg. Muscles at the hip, by acting on the femur, may pull the leg in various directions.

A large muscle in the calf of the leg is attached by a very large tendon to the heel bone. This is shown in Fig. 11, and can easily be felt under the skin at the heel.

When this muscle contracts it acts on the bones of the foot, which are bound firmly together. It is a lever of the second class, to pry up the body resting on it by the tibia. These muscles are all used in the leg in standing, walking, and running. The limbs should be studied in these actions.

The Divisions of the Body.—The evident parts of the body are the *head*, the *neck*, the *trunk*, and the

limbs. The limbs—the arms and the legs—are to be thought of as mere appendages of the body to serve its demands. The legs carry the body about, and the arms carry to it what it needs, defend it, and in a hundred ways attend to its wants.

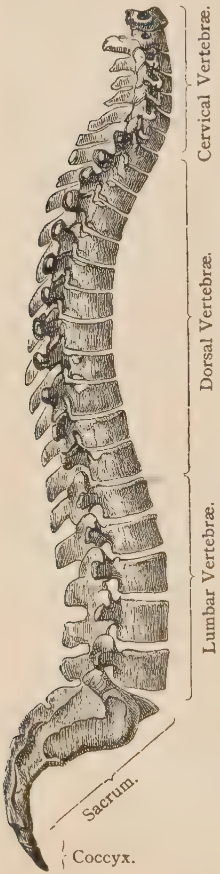

Fig. 12.
SPINAL COLUMN.

That the limbs may thus act, they must have a firm support to push against. The bony arches which carry them find this support in the skeleton of the rest of the body.

The Axial Skeleton.—The main foundation of this skeleton is the *central axis*, made up of the spinal column and the skull.

The Spinal Column.—The spinal column consists of twenty-six bones very firmly bound together into one firm beam. Its bones are twenty-four vertebræ, the sacrum, and the coccyx.

The vertebræ are divided into three groups: seven in the neck, the *cervical* vertebræ; twelve to which the ribs are attached, the *dorsal* vertebræ; and five in the loins, the *lumbar* vertebræ. The sacrum is the base on which the column of vertebræ stands, and serves as the place for the pelvic arch to brace against.

A Vertebra.—Each vertebra (Figs. 13 and 14) has a central part from which extend seven projections, called processes. These serve for the attachment of ligaments by which the vertebræ are joined in one mass. They also serve for the attachment of many muscles which move the limbs and the head, and accomplish other motions. Each vertebra has an opening in its posterior part. When the vertebræ are brought into line these openings make a canal, called

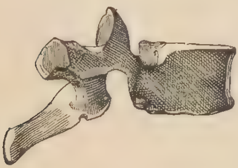

Fig. 13.

A Dorsal Vertebra.
Side View.

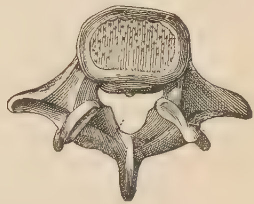

Fig. 14.

Vertebra seen from Above.

the *spinal canal*, in the upper part of which is the *spinal cord*, and in the lower portion are many *nerves.*

Bones of the Thorax.—The walls of the chest are supported by the twelve ribs on each side, the sternum or breast bone in front, and the dorsal vertebræ behind. The ribs end in cartilages in front. The cartilages of the first seven are joined to the sternum; those of the next three are joined together and to the seventh, and the last two are free in front.

The Skull.—The skull, the skeleton of the head, is placed on the upper vertebra. It consists of the *cranium* and the *bones of the face.* The cranium is the part that incloses the brain. If it is examined

by feeling it under the scalp, it will seem to be one spherical bone, but it is really made of plates which are so nicely joined together that the joints can not be detected until the bones are exposed. The whole eight make a box, with several holes in the floor.

The bone in the forehead is the *frontal*; the *occipital* is at the back, the two *parietals* at the top, the two *temporals* at the sides and bottom, in the region of the ear. The opening of the ear tunnels into it.

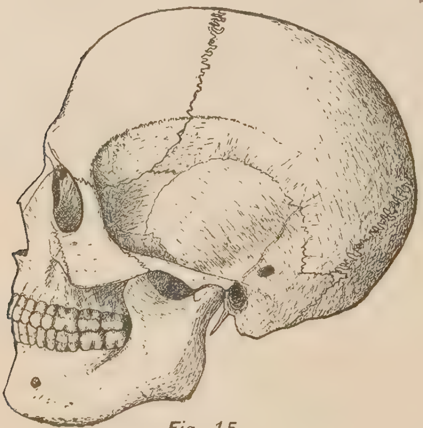

Fig. 15.

BONES OF THE HEAD.

The *ethmoid* helps form the floor in front, and continues into the face back of the upper part of the nose. The *sphenoid* is at the bottom of the box, and is very irregular in shape; its edges touch each of the other seven bones of the cranium, beside some bones of the face.

Bones of the Face.—These are fourteen in number. The only one free to move is the lower jaw bone, called the *lower maxillary*. This bone bears the lower teeth. It forms a joint with the temporal bone. It is drawn upward in closing the mouth by

muscles which can be felt in the cheeks, and is drawn down by muscles in the neck.

Determine what kind of lever it forms in these motions.

The *superior maxillaries* are those which carry the upper teeth. They meet in front and extend up on each side of the nose as far as the eyes. Two small bones, the *nasals*, form the bridge of the nose just beneath the eyes.

The two *malar* bones form the prominent ridges, one under each eye. A thin plate of bone helps form the partition between the nostrils, and is called the *vomer*. Two curved bones project into the passages of the nostrils. They are the *inferior turbinated* bones. Two very thin bones which form a part of the inner lower surface of the orbit of the eye are called the *lachrymal* bones.

The *hyoid* bone is a U-shaped bone in the front part of the neck. It can be felt just under the skin, immediately above the part called "Adam's Apple." Many muscles are attached to it, the chief of which is one in the tongue.

Identify these bones in the figure of the skull, and attempt to trace as many of them in your own head as come near the surface.

The Uses of Bones.—We have already seen that the main uses of the bones of the *arm* and *leg* are for levers, or for the attachment of muscles to produce motions.

The *shoulder and pelvic girdles* are for the attachment of muscles, and to serve as braces for the limbs to push against. Many of the *bones* of the *head* serve

for the attachment of muscles, which make it possible to carry the head erect, and to move it about.

Some of the bones of the head are the necessary place of attachment of muscles to move the lower jaw, the bone of the lower jaw being itself a lever with motion as its chief purpose.

The *spinal column* is the main region for the attachment of the great muscles of the body, and is at the same time constantly acting as a lever. The ribs make rigid walls to a part of the body to act as the sides of a bellows in breathing. They also act as levers, both in taking in the air and in expelling it from the lungs.

The skeleton, then, has two chief functions: to act as levers, and to furnish surface for the attachment of muscles to work these levers.

Secondary Uses of the Bones.—Some of the bones are incidentally used for protecting parts from outside injuries, as in the case of the bones of the skull, guarding the brain, and the bones of the chest, guarding the heart, while they perform their more important functions as well.

Different Kinds of Skeletons.—All those animals which have a spinal column are called *vertebrates*. They all have more or less developed hard parts, composed of bone or *cartilage* (to be described presently), imbedded in their bodies, to act as does the skeleton of man. Because this kind of a skeleton is so placed it is called an *endoskeleton*—that is, an inside skeleton.

But in animals like the crawfish, which performs vigorous motions by means of muscles, the same

necessity exists for hard parts to act as levers, and for the attachment of muscles. In this animal, the skin, by becoming a rigid crust, only flexible at the joints, furnishes this means. The muscles inside the limbs and the body are attached to this hard crust, and its divisions serve the same purpose as the bones of man. This kind of a skeleton is called an *exoskeleton*—that is, an outside skeleton. In vertebrates there is also an exoskeleton represented in the nails, hairs, and epidermis of man, but in vertebrates it does not serve as an organ of motion. The insects, crawfishes, and crabs have the exoskeleton greatly developed for the purpose of motion.

An examination of the crawfish or some large insect will allow the arrangement of the muscles and of the exoskeleton to be much better understood.

Animals without a Skeleton.—There are animals without a skeleton of any kind, but they are not able to accomplish very powerful motions. Most of them live in water, where they are partly or wholly held up by the water and have only slow motions. Most of these animals are very small and can be seen only by the microscope.

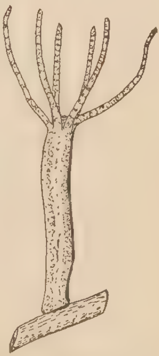

Fig. 16.

A FRESH-WATER HYDRA. MAGNIFIED.

As they have no skeleton, they generally have no muscles. Consequently they are wholly unable to accomplish a very great number of motions, and these must be very indefinite.

One such animal is found growing on sticks and

leaves in our ponds and ditches, and is called the Fresh-water Hydra. Fig. 16 is a drawing of one. This represents the animal magnified. The animal is only about half as large as one of the six arms shown in the picture.

It can swing itself about, stretch out its six arms, and if a small animal comes within its arms, it can close them down on it and pull it into the hydra's mouth, which is in the center of the end bearing the arms.

This it does by contracting the whole substance of its arms and body. We can readily see the great advantage of an arm like our own over such an arm. Our arm has part of its substance contractile, the muscular substance, and part of it resisting, the bones, so that we can get muscles and levers. What a very great number of kinds of motions such an arm can accomplish above those of a soft mass of flesh having the power to contract, but not being rigid enough to be extended except when floating in water!

This little animal will serve to emphasize more strongly the advantage of a *skeleton.*

Structure of a Bone.—A living or fresh bone consists of a hard portion whose sides are covered with a membrane of the same substance as that of the tendons. The ends are covered with layers of cartilage. In the central portion of the long bones, like the femur, the hollow space is filled with a fatty substance called *marrow*. The hard part is thickened at the central portion of the bone.

In the ends of the bone the hard substance is ar-

ranged like the fibers of a sponge, the spaces being filled with a substance called *red marrow.* The bones generally have near their extremities rough places, or even projections, called *processes*, to furnish surface for the attachment of tendons and ligaments.

Articulations.—The word *articulation*, in the study of the bodies of animals, is applied to the joining of two bones. We have had occasion to refer to these, in the study of the muscles, as *joints.* The word joints, however, is generally applied to the joining of two bones in such a way as to allow motion, such as exists between the bones of the fingers. These joints are sometimes called *movable articulations.*

Fig. 17.

SHOULDER JOINT, WITH SOME OF ITS LIGAMENTS.

An *immovable articulation* is one where the ends or edges of the bones are so firmly joined together as to allow of no motion. Examples of joints of this class are found between the surfaces of the bones of the head.

The edges of the bones of the cranium are very irregular in outline, and lock into each other and make the whole one covering of the brain. These lines of junctions of the two bones are called *sutures*, and can be seen in the figure.

This arrangement in the skull allows the whole to

act as a firm covering, yet if any part should become fractured, the fracture might be checked at the junction of the bone.

The movable articulations, such as the joints in the fingers, are formed especially to allow the easiest motion. Each joint is formed on the same plan.

The ends of the two bones fit together very nicely, and are covered with *cartilage*, which is a very smooth and a very elastic substance. Over the layers of cartilage, fastened firmly to it, is a membrane which secretes a liquid which keeps the surfaces of the joints moist.

This arrangement allows motion with the least friction. The elasticity of the cartilage lessens the jarring effects of the motions of the body.

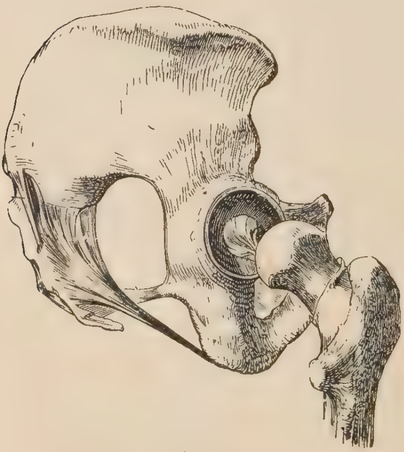

Fig. 18.

Hip Joint, with Ligaments removed, except the one on the Head of the Femur.

The bones are held firmly to their places by very strong bands known as *ligaments*. These are shown in the figures of the joints given. These bands are of the same substance as the tendons. They are woven into the sheath of the bone.

Classes of Joints.—When one end of the bone

forms a round surface which fits into a cup, the joint is known as a *ball and socket* joint, an example of which is seen in the hip joint. This sort of a joint allows motion in all directions.

A *hinge joint* is one in which the motion is, as at the elbow, in but two ways.

A *pivot* joint allows motion around an axis. This kind of a joint is found between the first and second cervical vertebræ. By its means the head can be turned in all directions.

Determine what kinds of joints are in the other parts of the body.

Questions for Review.

1. Name the bones of the foot, and describe the position of each.
2. How do these compare with the bones of the hand?
3. How is the arch of the foot formed?
4. On which does the weight of the body rest?
5. Describe the position of the tibia.
6. Where is the fibula?
7. Where is the femur? Describe it.
8. Give the position and use of the hip bone.
9. What is the pelvic arch?
10. Why must it be stronger than the pectoral arch?
11. What is the patella and what is its use?
12. How are the bones of the leg used?
13. Describe the motions of standing, walking, and running, as you may observe them by observation of the actions.

14. What are the divisions of the body?

15. How are the limbs to be regarded?

16. What is necessary in the structure of the body that the limbs may act?

17. What is the main part of the skeleton?

18. Of what is the spinal column made up?

19. Give the groups of vertebræ with the number and location of each.

20. Describe a vertebra.

21. What are the processes for?

22. What is the spinal column, and how is it formed?

23. What is placed in it?

24. What bones support the walls of the thorax?

25. Give the number and position of the ribs.

26. How are they connected?

27. What are the divisions of the skull?

28. Describe the location of each of the bones of the cranium.

29. Point out the positions of as many as you can on your own head.

30. Give the positions of the bones of the face.

31. What kind of a lever is the lower maxillary?

32. Point out each of these bones in the picture of the skull.

33. Point them out as far as you can in your own face.

34. What are the functions of the bones?

35. Show this to be the case in the different parts of the skeleton.

36. What are some of the secondary uses of the bones?

37. Give as many examples as you can of these.

38. Which are the vertebrate animals?

39. What are the two kinds of skeletons among animals?

40. Describe the skeleton of the crawfish.

41. How are its muscles attached?

42. What constitutes the exoskeleton in man?

43. What common animals, beside the crawfish, have well-developed exoskeletons?

44. What of animals with a skeleton?

45. How do they move?

46. What advantages arise from the possession of a skeleton?

TABLE OF THE BONES.

I. Axial Skeleton.

A. Skull, 28.

1. Cranium, 8.

a. Frontal, forehead,	1
b. Parietal,	2
c. Temporals, temples,	2
d. Occipital,	1
e. Sphenoid,	1
f. Ethmoid,	1

2. Face, 14.

a. Inferior Maxillary, lower jaw,	1
b. Superior Maxillaries, upper jaw,	2
c. Palatine, palate,	2
d. Nasal Bones, bridge of nose,	2
e. Vomer,	1
f. Inferior Turbinated,	2
g. Lachrymals,	2
h. Malars, cheek bones,	2

3. Bones of the Ear, 6.

a. Malleus,	2

b. Incus,	2
c. Stapes,	2
B. Spinal Column, 26.	
1. Cervical, or neck vertebræ,	7
2. Dorsal, or thoracic vertebræ,	12
3. Lumbar vertebræ,	5
4. Sacrum,	1
5. Coccyx,	1
C. Ribs, 24.	24
D. Sternum, 1.	1
E. Hyoid, 1.	1

II. Appendicular Skeleton.

A. Shoulder Girdle, 4.	
1. Clavicle, collar-bone,	2
2. Scapula, shoulder-blade,	2
B. Upper Extremities, 60.	
1. Humerus,	2
2. Radius,	2
3. Ulna,	2
4. Carpals, wrist bones,	16
5. Metacarpals,	10
6. Phalanges,	28
C Pelvic Girdle 2.	
1. Os innominatum,	2
D. Lower Extremities, 60.	
1. Femur, thigh bone,	2
2. Tibia,	2
3. Fibula,	2
4. Patella, knee-cap,	2
5. Tarsals, ankle bones,	14
6. Metatarsals, bones of the instep,	10
7. Phalanges, bones of the toes,	28

CHAPTER IV.

THE STUDY OF THE HUMAN BODY.

Divisions of the Subject.—Having now become familiar with many of the objects in the study of the human body, some time may be taken to learn how the subject is divided and what its divisions are called.

In the first chapter, in making a study of the hand and arm, we learned many facts which we can separate into two classes.

The Study of the Structure of the Body.—One class includes all those facts in regard to the form and position of each part, together with the name of each. These facts teach us how the arm is constructed. All such facts—that is, those that pertain to the structure of the human body—are put under the subject of *Anatomy*. *Anatomy* is the science which treats of the structure of the body.

The Study of the Uses and Properties of the Parts of the Body.—The second class of facts is those pertaining to the uses and properties of the parts of the arm; for example, what muscles do in general and what each muscle does in particular; how bones act as levers, the tendons as strings; and what are the properties of each which make it fit for these actions. All such facts—that is, such as pertain to the uses and properties of parts of the body—

are included under the subject of *Physiology*. *Physiology* is the science which treats of the uses and properties of the parts of the body.

The Study of the Health.—In learning how to keep the parts of the body in healthy action, how to avoid injuries and disease, we are studying a third subject, known as *Hygiene*. *Hygiene* is the science which treats of the health of the body.

The Relations of these Sciences to Biology.—These sciences are but small divisions of a subject including many others, which is known as *Biology*, the meaning of which science we should know. The human body is only one among thousands of living forms that are on the earth.

The forms are the plants and animals and they appear to be very different from each other. An oak tree does not seem in many ways like a turnip, but in reality they are very much alike. The differences are mainly in form and size. All plants have a great deal in common. It is the same with animals. All have much in common, as widely different as they are in form and size.

They could be thrown into a few groups, in which all the animals of a group would be alike in very many respects; as, for example, the birds. Nearly all the parts of an elephant are found in a mouse.

Bones, muscles, nerves, and all in considerable detail are present in each and arranged on just the same plan, so that the same names can be given to most of the parts.

Even animals and plants are alike in a great number of ways. This similarity that exists among all

these organisms has led to the grouping of all the sciences which treat of plants and animals under one head, called *Biology*.

If, while we are studying these lessons on the human body, we should constantly observe the lower animals in their habits, in their methods of motion, how they use the parts which correspond to those in man, much pleasure would be derived from such study. It would also add greatly to our knowledge of living beings in general and of the human body in particular. And, better than either of these, in this exercise we should learn to see and to think with greater skill.

The divisions of Biology are numerous and need not be discussed here, but they are all connected with the study of animals or plants. From this fact arise two great divisions of Biology, which are *Zoology* and *Botany*, used in the widest sense of the terms. The anatomy and physiology of the human body is but a part of the general subjects of anatomy and physiology of all animals.

In the study of the human body we are learning many facts which are true of a great number of the lower animals. In studying many of the lower animals we should learn many facts that are also true of the human body.

The knowledge of any one animal or plant gives us some knowledge of the whole living world, a knowledge which is becoming rapidly extended and more and more interesting as it progresses.

The Meaning of Different Forms of Living Beings.—The wonderful number of forms among

plants and animals are to fit each to the particular set of surroundings in which the animal or plant is found.

For example, every part of the crow helps it in the life it lives. Every part of a blackberry bush is also suited to its kind of life. The same may be said of every plant and animal, no matter how large or how small or of what shape.

The human body is also in all its parts fitted to the life of a human being.

Questions for Review.

1. What is Anatomy?
2. What is meant by the term structure?
3. Give an example of the study of the anatomy of a part.
4. What is Physiology?
5. Illustrate the definition from the study of the arm.
6. What is Hygiene?
7. Of what general science are all these a division?
8. What is said of the similarity of all living things?
9. What of the similarity between the oak and other plants?
10. What is Biology?
11. What connection is there between the study of the human body and that of other animals?
12. What are the two great divisions of Biology?
13. What advantages have animals in their different forms?
14. Illustrate this from your own observations.

CHAPTER V.

TISSUES, ORGANS, AND SYSTEMS.

Tissues.—In the study of the muscles and bones it was seen that a muscle or a bone is not composed of a single substance, but of several different materials. For example, the muscle has in it a part that will contract, and a part which ties it to the bone—the tendon. The bone has in it a hard part, but at the end there is the elastic cartilage, and also fastened to it are the ligaments.

These materials which make up the parts are called *tissues*.

The tendon is made up of *connective tissue*. It is used to make the ligaments for tying bones together. It is a strong, flexible material, and is well fitted for fastening the parts together, or for making a framework and support for other parts. There are two kinds of connective tissue: one is *elastic* and the other *inelastic*. The inelastic variety is used in tendons and ligaments, for it is plain that if the parts which hold the bones together in a joint were elastic, the joints would constantly be giving way. If the muscles were fastened to the bones with cords that would stretch, they would work at a disadvantage, and could not lift heavy weights at all. Elastic india rubber would not be good material for the harness of a horse.

In the muscle, the substance which contracts is called *muscular tissue.* This contractile material is placed wherever motions are to be produced. It is held together by connective tissue.

The hard material of a bone is called *osseous tissue.* It is used wherever a rigid rod for a lever, or a strong post for the attachment of muscles, or a hard plate is needed. It has in it some mineral substances of the same composition as *gypsum*, a kind of stone, and common lime stone. Osseous tissue could be spoken of as tissue partly petrified.

Cartilaginous tissue is a very elastic material, yet very firm. It is used on the ends of the bones at the joints, as we have seen, and in other positions where a certain amount of rigidity and elasticity is required.

The other materials of the body are *nerve-fiber* tissue, placed in the nerves; *nerve-cell* tissue, in parts of the brain and spinal cord; *fatty tissue*, found in various parts of the body; *epidermal tissue*, the material for the nails and outer thin layer of the skin; and the *epithelial tissue*, the thin layer of the alimentary canal. The principal substance of the glands is called *glandular tissue.* In every part devoted to the use of the senses, such as the eye, ear, etc., is a special tissue that is affected by the light, sounds, etc. This is called *sense-organ tissue.*

These few kinds of materials are used in making up the parts of the body, each being just where its peculiar property recommends it.

If one intends to build a house, a ship, or a wagon, he selects materials, each piece of which will be suited for what it is to do in the thing made. These mate-

rials are iron, ropes, wood, stone, brass, glass, and so on. In the same manner in nature, in the formation of the different animals certain materials are used. These materials, in all but the lowest in the scale, are about the same as those found in man, and used for the same purposes just given above.

As the only tissues which we can examine in our own bodies are the epidermal tissues on the outside of the skin and the epithelial tissue lining the mouth, we should examine the others in the lower animals to understand what is meant by them. Most of these materials can be seen in their natural positions in the leg of some small animal. A piece of meat prepared for cooking would, of course, show some of these tissues.

Organs.—A part of the body like the brain, liver, or eye, which is somewhat separate from the parts around it, and which performs some special operation, is called an *organ.*

An organ itself is usually made up of several tissues. For example, in the eye there are epidermal, nervous, muscular, and sense-organ tissues, all held together by connective tissue.

Systems.—When all the parts of one kind of the body—for example, the bones—are considered together as one large group apart from the others, it is called a *system.* Thus we have the *bony system* (the skeleton), and the *muscular system,* which were treated in former chapters. Besides these we have the *nervous system,* the *circulatory system,* and the *digestive system,* to be studied later.

The separation of the body into organs and sys-

tems helps us to see the whole body more clearly, but we must not forget that in reality these parts are mingled together, as seen in the arm. They are so closely connected that they can work together in harmony and not in confusion.

Organization.—A school is organized when its members are divided up into groups or classes, and each group taught what to do and when to do it. By this arrangement the whole school can accomplish a great deal more work than if no such arrangement existed.

It is only by organization that a large manufacturing establishment can accomplish its work. In a machine shop there may be employed hundreds of men. These men are divided into groups and put into different parts of the building, each group and even each man is instructed in just what is to be done. His duty is to work on some one part of a machine that is being made. When the work of all is put together the product may be a very large and fine engine, which it would be impossible for any one man to make if he spent his whole life at it.

Division of Labor.—Dividing the work required to make an engine among different workmen is called "*division of labor*."

This principle is practiced in every home and in every shop where more than one person is working. It is at the foundation of all our life in communities.

Almost every thing we have in the house, that we wear, that we use in school or elsewhere, is the result of the advantage of the division of labor.

Determine for yourself how this is true of the bread

you eat, the pencils you use, or of any other object in common use.

Now, the bodies of animals are formed in accordance with the principle of the "division of labor." The life of a single day requires many motions, also seeing, hearing, smelling, tasting, feeling, circulation of the blood, breathing, digesting, secreting, the making of heat, and many other processes.

These processes are given out to different groups of tissues in the body called organs, each of which performs its own work without attempting any other or interfering with any other.

This is *organization* in the body, and as all plants and animals show this in a greater or less degree, they are called *organisms.*

There is a great difference in animals in the degree to which the principle of the division of labor is carried out.

In a former chapter this was shown in the comparison of the arm of a hydra with that of a human being. The comparison may now be extended. The hydra's body is of a single tube made of two layers of substance of the same material as that of the arms around the mouth. These tubes can move, digest, secrete, and perform many processes. It differs from the parts of a larger animal in not having the labor of these processes so completely divided among its different parts.

And when we compare what the hydra can do with what a squirrel, a bird, or a man can do, we can see of what very great advantage the principle of the division of labor is.

Plan of the Body.—The systems in the body mentioned above are arranged in a certain definite way, which is the same in all animals which have a backbone. It may be remembered that the plan of the bony skeleton is a central axis from which all other parts are extended. In this lies the central axis of the nervous system, from which its branches also extend.

Just in front of this lies the central axis of the blood vessels, from which its divisions are given off. **This is in a cavity**, divided into two parts in man, one for the lungs—the thorax; another for the stomach, intestines, etc.,—the abdomen. Extending through the body is the tube of the alimentary canal. The whole of the body is covered with the skin, which is continuous with the lining of the alimentary canal.

Fig. 19 is a diagram which shows the position of these parts. It represents the positions which would be shown by cutting through the trunk of the body. The upper part is at the back of the body, the lower part at the front.

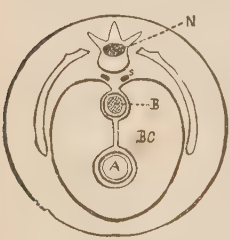

Fig. 19.

Plan of the Body in Cross-section.

The explanation is given in the text.

The outside ring represents the skin. The figure at the top with three parts is the spinal column; the black spot marked *N* is the spinal cord, the nervous axis; *B* is the aorta, the axis of the circulatory system; *A* is the alimentary canal; *BC* is in the space which represents the cavity of the thorax or of the abdomen, according to the place

of the section. Between the cavity *BC* and the skin are the bones and muscles of the body.

Now, a slice across any vertebrate—that is, mammal, bird, reptile, frog, or fish—would show just the same arrangement. Consequently this may be called the plan of a cross-section of the vertebrates.

Questions for Review.

1. What are tissues?
2. Of what kind of tissue is a tendon?
3. What are the properties of this tissue?
4. In what other positions is it used?
5. What are the varieties of connective tissue?
6. What is muscular tissue?
7. What is its peculiar property?
8. Of what tissue is the hard part of a bone composed?
9. What is its composition?
10. In what positions is this tissue used?
11. What is cartilaginous tissue?
12. Where is it used in the body?
13. Give examples of other tissues.
14. To what are the tissues in the body compared?
15. What is an organ?
16. Of what is it composed?
17. Give three examples.
18. How is a system made up?
19. Illustrate this.
20. What is meant by the term organization?
21. How does a school illustrate this?

22. How is it shown in the management of a large machine shop?

23. What is meant by the term division of labor?

24. Illustrate this.

25. Show how the principle of the division of labor is made use of in the body.

26. What differences are seen in animals in the degree to which this principle is carried out?

27. What advantages arise in the body in making use of this principle?

28. Illustrate this by comparison of the hydra to a squirrel.

29. What is said of the plan of the body?

30. Draw a diagram illustrating the plan of a section of the body.

31. Which of the lower animals possess this same plan?

CHAPTER VI.

ANATOMY OF THE CIRCULATORY ORGANS.

The Use of Blood.—We have long known that we require food every day, and that water is also an absolute necessity, and that we must have air every moment.

The more active we are the hungrier and thirstier we become, and the more food do we actually take. We may not notice that we use more air, yet it is true.

What is the cause of these demands? Just for our present purpose we may say that in work the body consumes the food, water, and air, and, in consequence, there must be a further supply of these substances. When we say that the body needs these, we mean nothing more than that the parts of the body need them—that is, the muscles, the bones, the nerves, and the like. Further, since work causes an increased demand, it must be the parts that are working most that are in need of the food most. Those organs are the muscles, but, of course, many other parts work with them.

Now, we know that the food we eat does not go to the muscles in the form in which we see it. The food of the muscles and of the other parts of the body is the blood.

They live upon the blood, which is formed from the food, the water, and a part of the air, the gas oxygen. The muscles, the nerves, and indeed every tissue in the body, gets its food, drink, and oxygen from the blood. When, then, we take more food or drink, or breathe faster, it is to add more food, water, or air to the blood to take the place of what the tissues of the body have used in the work.

How the blood receives the supply of food and drink we take, and how its supply from the air is obtained, we shall study later in the chapters on Digestion and Respiration. At this place we shall study the blood and its motion through the body.

The Blood in the Hand.—The hand may answer again as a beginning point for our study. Many accidents have taught every one that the hand is full of blood. If it is pierced at any point, even with a very fine needle, the blood will flow from it, the only exceptions being the very thin outer layer of the skin, the epidermis, and the nails.

How does the Blood exist in the Hand?—It might be supposed from the experiments with the needle that the blood is in the hand as water may be in a sponge, but it can easily be shown that such is not the case. If the hand is allowed to hang down quietly for a short time, and the back is observed, a network of ridges of a bluish color will appear under the skin, and the whole hand will be of a deeper pink color. Now, if the hand be held above the head, it will be observed that this network will become very much less prominent, if, indeed, it does not entirely disappear. The network of ridges con-

sists of tubes which are carrying the blood from the hand. When the hand is held down the blood in them has to flow up-hill, and consequently the tubes all become well filled with the liquid. The pink color shows that the rest of the hand has more blood in it.

Now, when the hand is held up the blood runs out of these tubes better, and they are left nearly empty. There is less blood left in the rest of the hand also. To show that the blood is flowing from the hand toward the shoulder, one can press the blood out of the tubes of the back of the hand and watch it fill again. It will always be seen to fill from the direction of the fingers.

How does the blood get into the hand? Find the place above the wrist where you can feel the beating of the pulse. It is just between the skin and the end of the radius. This beating is in one of the tubes which bring blood to the hand. That the blood is coming from the shoulder to the hand can be proved by pressing firmly on the tube until it is closed, and then it will be found that the stroke of the beat is on the shoulder side of the wrist.

The Names of the Tubes.—The blood is running along this and other tubes deeper in the arm, on its way to the hand. These tubes are called *arteries.*

As it goes to the hand, the arteries divide into many branches which become smaller as they branch. These go to the muscles, bones, and skin, which they penetrate, and in which they finally branch until they are so minute that they can not be seen without a

microscope. These very fine divisions of the tubes are the *capillaries.* They are very numerous, making an extremely fine network, which brings the blood to even the minutest divisions of the muscles, bones, etc.

This network of capillaries soon unites its vessels into larger and larger ones, which leave each muscle, bone, and other parts in the same way that the arteries enter them.

These returning tubes are the *veins.* The smaller veins join into larger and larger ones, some of which we have observed on the back of the hand. Fig. 20 shows how they appear in some tissues. The picture represents them with all the tissues removed from the blood vessel. The largest white vessel may represent the smallest artery, which is divided up to form the network of capillaries, and the dark vessel the small vein with the returning blood. To sum up what has just been learned of the hand, it may be said that the blood comes into it by arteries which divide until they finally become capillaries, which are in every part except the nails and the outside layer of the skin, and from these it returns by means of veins.

Fig. 20.

RELATIONS OF ARTERY, VEIN, AND CAPILLARIES.

The Blood in other Parts of the Body.—What has just been learned of the hand is true for every other part of the body. To every part arteries are

distributed, ending in capillaries which join to form veins.

When the hand hangs down, the blood must be forced up-hill the length of the arm. When the hand is held above the head, the same must be done in the arteries. In either case it must be pushed along with great force. If the arteries and veins were exposed to view, we could see them running up the arm, past the shoulder, across the upper part of the chest, and finally ending in the *heart*. The general view of the arteries is shown in Fig. 23.

The Heart.—The heart is a force-pump which night and day pumps the blood into the arteries with enough force to send it on through the capillaries and back to itself through the veins.

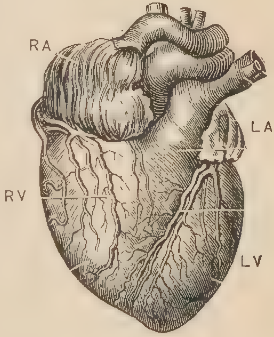

Fig. 21.

THE HEART.

RA, right auricle; *RV*, right ventricle; *LA*, left auricle; *LV*, left ventricle.

The heart is in the lower part of the cavity of the chest. It is somewhat of the shape of a cone, with the point turned down and a little to the left, with the broad end turned toward the right shoulder. One's heart is about the size of his fist.

The position of the point or apex of the heart is easily determined by the beats it makes against the side of the chest, between the fifth and sixth ribs, a little to the left of the central line.

If the open hand be laid on the chest, so that the

tip of the middle finger is at the point where the beats are felt, and the wrist is turned toward the right shoulder, the hand will be over the heart.

The Interior of the Heart.—The heart is divided into four rooms, two at the broad (upper) end, the *auricles* (Fig. 22), and two below these, in the narrower end, the *ventricles*. There is a partition between the auricles, and one between the ventricles. The auricles and ventricles are distinguished as *right* and *left*.

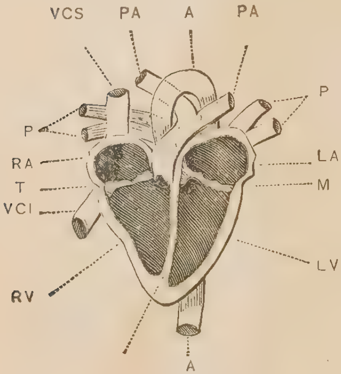

Fig. 22.

DIAGRAM OF THE HEART.

A, aorta; *PA*, pulmonary artery; *VCI* and *VCS*, vena cava inferior and vena cava superior; *T*, tricuspid, and *M*, mitral valve. The other letters same as in preceding figure.

Between each auricle and the ventricle below it are flaps composed of a strong membrane. These flaps are arranged as *valves*, which lie against the ventricles when the blood passes from the auricles to the ventricles; but on an attempt of the blood to return to the auricles, these valves are closed by the current. They are shown closed in Fig. 22. The one on the right side, the *tricuspid* valve, consists of three flaps; the one on the left, the *mitral* valve, consists of two flaps. There are also valves at the origin of each of the large vessels leaving the heart, called *semilunar* valves.

The Vessels Connecting with the Heart.—From

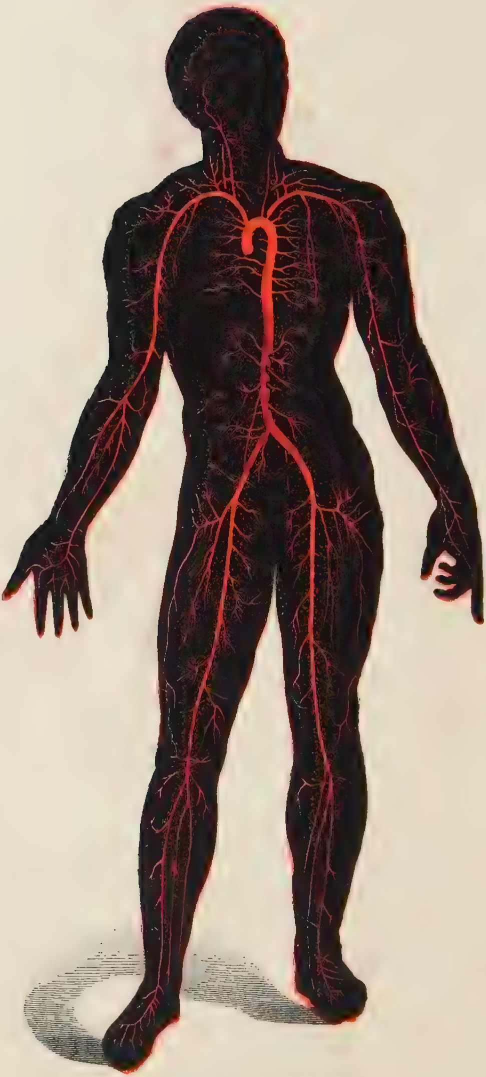

Fig. 23.

Distribution of the Arteries.

the left ventricle there arises a large artery, the *aorta*, whose branches are distributed to all parts of the body.

From the right ventricle there arises an equally large vessel, the *pulmonary* artery. Its divisions go to the lungs.

Opening into the right auricle are three large veins: the *superior vena cava*, which receives blood from the veins coming from the head, the neck, and the arms; the *inferior vena cava*, which receives the blood coming from the legs and most of the trunk; and the vein from the heart itself, the *coronary* vein.

Opening into the left auricle are four *pulmonary* veins, bringing blood from the lungs.

The Aorta and its Divisions.—The aorta, as soon as it leaves the heart, makes a turn called the *arch of the aorta*, and passes down just in front of the spinal column. It gives off branches at the very start from the heart, and along its whole course. These branches subdivide and go to each part of the body, where they end, as we have learned in the study of the hand. Trace them in the figure representing the arteries.

The Veins.—After the blood is gathered up by the small veins it returns by a number of larger veins, which correspond in their distribution generally in each part of the body to the arteries.

Structure of the Heart.—The walls of the heart are made up of muscular tissue. The valves are of connective tissue. There is a connective-tissue layer covering the heart. A sac called the *pericardium* surrounds the heart. Between it and the heart

is a liquid known as the *pericardial liquid.* This arrangement allows the heart to beat with as little friction as possible. The walls of the ventricles are much thicker than those of the auricles, those of the left ventricle being thicker than those of the right. The greater amount of work done by the left ventricle requires this.

Structure of the Blood Vessels.—The *arteries* have strong walls of connective tissue, with some muscular fibers, especially in the small arteries. The connective tissue is largely of the *elastic* variety, so that the walls of the arteries will stretch like rubber.

Fig. 24.

A Vein laid open, showing its Valves.

The *veins* have much thinner walls, which are mainly of *inelastic* connective tissue, and consequently they will not stretch. The small veins have some muscular fibers in their walls. Many of the veins have valves in them, formed by pouches of connective tissue, which allow blood to pass toward the heart but prevent it from going the other way.

The capillaries have extremely thin walls.

The Divisions of the Circulatory System.—The aorta, its branches and their subdivisions, the capillaries into which they empty, and the returning veins that empty into the right auricle, are known as the vessels of the *systemic circulation.* The pulmonary arteries, the capillaries of the lungs, with the pulmo-

nary veins, are the vessels of the *pulmonary circulation.*

Questions for Review.

1. What is the cause of hunger and thirst?
2. Where are the substances called for needed?
3. How does work cause an increased demand?
4. What is the food of the tissues?
5. In what part of the hand is the blood?
6. How does the blood pass through the hand?
7. Prove it in the case of your own hand.
8. How does the blood come to the hand?
9. How does it leave the hand?
10. What are the names of the blood tubes?
11. How are they arranged with respect to each other?
12. Draw a diagram showing this arrangement.
13. Sum up what has just been learned of the course of the blood through the hand.
14. How do the parts of the body compare with the hand in this respect?
15. What in the circulation through the arm shows that the blood goes with considerable force?
16. What sends the blood out with this force?
17. Give the position of the heart.
18. Describe the heart.
19. Describe the interior of the heart.
20. Draw a diagram of a section of the heart, and locate the parts in it.
21. What vessels are connected with each room in the heart?
22. What is the position of the aorta?

23. What of its branches?

24. How are the veins distributed?

25. Of what tissues is the heart composed?

26. What is the pericardium and what is its use?

27. Describe the structure of the arteries.

28. The structure of the veins. Of the capillaries.

29. What constitutes the systemic circulation?

30. What constitutes the pulmonary circulation?

CHAPTER VII.

THE PHYSIOLOGY OF THE CIRCULATORY ORGANS—THE BLOOD.

The Course of the Blood in Circulation.—The course of the blood in circulation is represented in the diagram in Fig. 25. This shows how the heart is a double pump, one portion being placed in each of the systems of circulation, the pulmonary and systemic.

As the valves are shown, the blood can flow but one way, and before completing the circuit must pass through the heart twice. It must also pass through at least two sets of capillaries—those of the lungs (pulmonary capillaries), and those of some other part of the body (systemic capillaries). That portion of the systemic circulation which carries the blood to the stomach, intestines, and spleen, and from them through the liver to the inferior vena cava, is called the portal circulation.

We may now consider the action of each part of the circulatory system.

The Action of the Heart.—The blood flows gently from the large veins into the auricles, and they throw the blood into the ventricles with enough force to dash it up their sides, as water does up the sides of a glass when poured into it. This not only

fills the ventricles, but closes the valves between the auricles and ventricles.

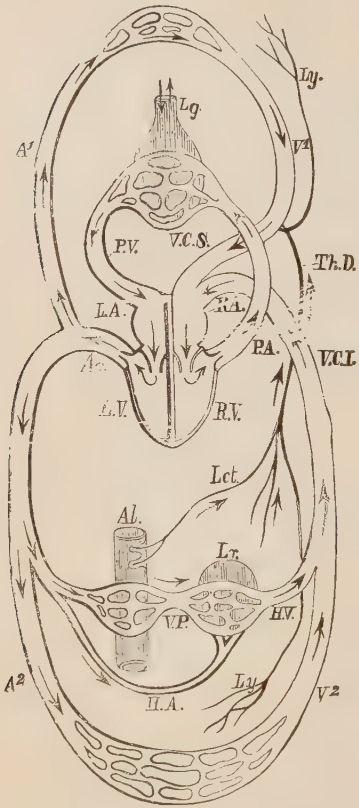

Fig. 25.

DIAGRAM OF THE COURSE OF THE BLOOD.

RA, right auricle; *RV*, right ventricle; *LV* and *LA*, left auricle and left ventricle; *VCI* and *VCS*, vena cava inferior and superior; *Ao*, aorta; *Lg*, lungs; *Al*, alimentary canal; *Lr*, liver; *VP*, portal vein; *Ly*, lymphatics; *Th D*, thoracic duct; *Lct*, lacteals; *HA* and *HV*, hepatic artery and vein.

Then the ventricles immediately contract and force the blood past the semilunar valves, the right ventricle into the pulmonary artery, and the left ventricle into the aorta. The heart is a very active pump, making about seventy-two strokes a minute.

The Blood in the Arteries.—The pulse felt near the wrist is caused by the shock given to the blood in the arteries by the beat of the left ventricle.

The capillaries are so small and numerous that their walls make a very large surface for the blood to flow over. The friction from this surface is great enough to hold the

blood back. As the heart keeps up the pumping, the arteries become so full of blood that their elastic walls are stretched to give it room.

Every time the heart beats the walls of the whole system of arteries spring out. It is this that we feel in the pulse.

Pressure of the Blood in the Arteries.—By being held back at the capillaries and forced on at the heart, the walls of the arteries stretching to receive it, the arteries become so crowded with blood that if an artery is accidentally opened the blood spurts from it with great force. If an opened artery were connected with a perpendicular tube the blood would rise five or six feet in it. This condition of the blood in the arteries is like that of water in a reservoir; it is under *pressure.*

The Blood in the Veins.—In the veins the blood flows by a steady stream, very slowly in the smallest veins, and gradually quickening toward the heart. If a vein be opened the blood flows from it, but with little force. It is not under very much pressure in the veins.

The Use of the Blood Pressure in the Arteries.—The advantages of the arrangement just discussed are:

First.—While the blood is thrown out from the heart in jerks, it will flow into the capillaries in a steady stream. The pulse gradually decreases in force from the heart to the capillaries, where it disappears. This is a very important advantage. The walls of the capillaries must be thin to allow the blood to soak through them to the tissues. Thin

walls could not endure a stream of strong jets without breaking.

Second.—As the blood is under pressure on the arterial side, and under little or no pressure on the venous side, the amount of blood going to any organ may be regulated by widening or narrowing the arteries going to it. The muscular substance in the walls of the small arteries do this by contracting or relaxing.

This advantage is just as important as the first given, for without it there would be no means of regulating the supply of blood to each of the organs. All parts would receive blood equally at all times, whether they needed it or not.

The Action of the Capillaries.—It may be recalled that the blood is to supply the tissues with food, water, and oxygen from the air; but this is not all that the blood does. It also takes away from the tissues certain substances which they in their activity are constantly making, and which, if they remained in the tissues, would be very injurious to them.

Now, the changes between the blood and the tissues can take place only through the very thin walls of the capillaries. The liquid part of the blood, and whatever may be dissolved in it, can soak through the thin walls of the capillaries, and the substances dissolved in the liquid part of the tissues may soak through in some way to the blood, which carries them along in its current to be disposed of elsewhere by processes to be described in other chapters.

Then it may be said that all the changes between

the blood and the tissues take place in the capillaries, and that the object of the other parts of the circulatory system is to drive the blood continually through the capillaries.

Regulation of the Actions of the Circulatory Organs.—The heart is composed of involuntary muscles and can not be influenced by the will, but its rate of beating is often changed to suit the needs of the body. If one counts his pulse before performing some vigorous exercise, and again in a short time after he has begun it he will find the pulse in the latter case more frequent. The heart has been stimulated by its nerves to greater action.

At the same time, in the parts of the body that are in action the small arteries dilate a little by their muscular walls relaxing. This allows a greater amount of blood to flow into them. When any part is not in vigorous action, small arteries which furnish it with blood contract their walls and lessen the supply.

These actions are regulated by nerves in a way to be studied when we come to the nervous system.

Properties of the Blood.—The blood is familiar to every one as a bright red liquid. The shade of red varies in the body from the bright red to a very dark red. Seen through the thin walls of the veins, it appears blue.

The microscope shows that the blood is composed of a nearly transparent liquid, in which is suspended a cloud of immense numbers of little particles.

The liquid is *plasma*, and the particles are *blood corpuscles*.

Blood Corpuscles.—There are two kinds of blood corpuscles—the *red* and the *white*.

The red corpuscles, when very greatly magnified, are seen to be thin round disks with slightly concave sides. They are about $\frac{1}{3200}$ of an inch in diameter. Although they are called red corpuscles, their color is but a faint yellow. It is only in great numbers that they give the mass the appearance of red. They differ some in shape and size in different animals. Fig. 26 shows the appearance of the red corpuscles from the human blood, and Fig. 27 those from the blood of a frog. The white corpuscles are few in number compared with the red. They are colorless and of irregular shape.

Fig. 26.

Human Red Blood Corpuscles. Highly Magnified.

The Use of the Red Corpuscles.—The red corpuscles in the lungs take up oxygen, one of the gases of which the air is composed, and carry it to the tissues, which require oxygen constantly.

Fig. 27.

Blood Corpuscles of a Frog. Highly Magnified.

The Plasma.—The liquid part of the blood is very complex. It is receiving water and digested food from the digestive system all the time, and various substances which the tissues are constantly producing. It is very evident that the blood

must have dissolved in it all the substances which are required for the growth of the tissues, as they have no other source of supply.

Coagulation.—Soon after the blood is taken from the blood vessels it has the power to form into a mass which has the appearance of jelly, called *clot.* This process is called *coagulation.* This is accomplished by some substances which are always in solution in healthy blood. But the moment that the blood comes in contact with some other substance than the uninjured wall of the blood vessel, these substances form into very fine threads throughout the whole mass of the blood, holding the corpuscles entangled in their network.

The Use of Coagulation.—The power of clotting is a very important one. It is the method by which the blood can firmly plug up an opening made in the walls of the vessels. Without this, slight wounds would lead to bleeding to death. As it is, any but the larger arteries can stop their own bleeding. A clot will be formed even in one of the large ones also if it be held some time with a ligature.

Effect of Alcohol on the Heart.—(For discussion of effects of alcohol on the body, see pp. 185–191.) When any substance is taken into the body and it is seen that soon the activity of the heart is changed, it is impossible to say whether this effect on the heart is direct or reflex; *i. e.*, whether the substance gets into the blood and acts directly on the tissues of the heart, or whether it acts on other parts of the body and through the nervous system by reflex action affects the heart.

When all the proper precautions have been taken so that the results could be best understood, eminent physiologists have come to the conclusion that alcohol acts directly on the heart, weakening its action and decreasing its power of doing work. While the heart may beat faster through the presence of alcohol in the blood, the beats are not so strong, and the whole effect is to make the blood circulate less rapidly. Alcohol is thus regarded as having a paralyzing action on the heart.

When alcohol is given to a patient suffering from some disease or from an injury, the heart may be stimulated to greater action. In such a case the result, it is claimed, is not due to the direct action of the alcohol on the heart. But this whole question would require for its discussion much technical knowledge, and would be out of place in this book. It is here brought to notice simply to show that it is a more difficult subject than it seems to be considered by those who are ready to make so many definite assertions regarding it.

Whatever may be the immediate cause, however, it is well known that certain diseases of the heart are likely to follow the long-continued use of alcoholic drinks. The general vitality and tone of the heart are impaired, and it is thus rendered more liable to attack by disease. Its structure may become distinctly modified, fatty and connective tissue taking, to some extent, the place of muscular tissue, as seen in fatty degeneration of the heart. The smaller blood vessels in certain regions of the body may become in a measure paralyzed, and thus per-

manently distended. It is also claimed that alcohol has the power to take a part of the oxygen out of the red blood corpuscles, whose office, it will be remembered, is to carry oxygen.

Questions for Review.

1. Draw a diagram giving the course of the blood in circulation.
2. How many times must the blood pass through the heart in a complete circuit ?
3. Describe the action of the heart, giving that of each part in the order in which it occurs.
4. What is the cause of the pulse ?
5. What is the effect of the capillaries on the flow of the blood in the arteries?
6. What causes the blood pressure in the arteries?
7. What of the pressure in the veins?
8. How does the stream move in the veins? What of its velocity ?
9. What are the advantages of blood pressure?
10. Show how each accomplishes these ends.
11. What does the blood carry to the tissues? What away from them ?
12. How are these exchanges made between the tissues and the blood?
13. What in the structure of the capillaries permits this?
14. What may be considered as the aim of all the rest of the circulatory system except the capillaries?
15. How may the rate of the heart's beating be changed?

16. Illustrate this action.

17. How is an active part supplied with a greater amount of blood?

18. How is its supply lessened?

19. How are these actions regulated?

20. Describe the appearance of the blood.

21. Of what parts is it composed?

22. Describe the red corpuscles.

23. Describe the plasma.

24. What does it contain?

25. What is coagulation of the blood?

26. By what is it accomplished and when does it occur?

27. What is the use of coagulation?

CHAPTER VIII.

THE CHEMISTRY OF THE BODY.

Our Study of the Human Body thus far has shown us that it is really a very complicated machine, constantly active, at least in some of its parts. Further, it is always warm. We know that in some way the warmth and activity of the body are dependent on the food and oxygen. We shall now try to see what the dependence is. That will require a little knowledge of at least some very common substances, and how they act toward each other. This knowledge is usually put under the head of chemistry. The main facts are very easily observed in the action of an engine or of a common lamp.

What occurs in a Burning Lamp.—Let us make a brief study of this familiar lighting apparatus. The study of what occurs in a common lamp may be used to help in understanding some things which occur in the human body.

The Lamp Flame uses up the Oil.—As the lamp is burning, we may take note that it has oil in it, which, by means of a wick, is drawn up to a point where it is made to produce a flame, that gives out light and heat. After the lamp has been burning for some time, it is seen that the oil is disappearing, and if the flame is to be kept going we must keep adding the oil.

The lamp must have something else beside oil to keep it burning, and that is air. If we stop up the openings where the air enters the space about the flame, the lamp will soon go out.

The Flame uses Oxygen.—By many experiments, which each one can make for himself (and it is hoped he will do so), chemists have shown that air is composed of at least four gases mixed together. *Oxygen* and *nitrogen* are the main ones, but there is also some vapor of *water* and a very little *carbon dioxide*.

Of these gases in the air the lamp uses the oxygen. If the supply of this is cut off, the lamp will go out.

The lamp, then, while burning, is constantly losing weight by consuming the oil (and a very small amount of the wick), and in addition is using large quantities of oxygen from the air.

What becomes of these Substances.—Just to look at the lamp, it seems that they pass into nothing. But, of course, such can not be the case.

It is easy to show that there is a strong current of something from the top of the lamp chimney.

If we hold a cold piece of iron a short distance above the lamp, so that this current may strike it, the iron will soon become coated with *water*. If we hold an inverted wide-mouthed bottle over the chimney, so as to catch some of the gases, and afterward shake with the contents of the bottle a little clear lime-water (made by allowing a little lime to soak in some water), it will be found that the lime-water has become milky. Only one substance will affect lime-water in this way, and that is the gas *carbon dioxide*.

Evidently the water and carbon dioxide are coming out of the top of the lamp chimney. But as these are in the air all the time, it might be thought that nothing was proved by this. But if these experiments be repeated on the other air in the room, even from the heated currents from the top of the stove, they will not show the presence of these gases, because of the very small quantities in it.

The experiments succeeded with the air over the top of the lamp chimney because of the large quantities of water and carbon dioxide which came from the flame.

Relation of the Substances coming to and going away from the Flame.—The chemists have repeated this experiment more carefully, and find that if they weigh accurately every drop of oil and particle of wick consumed, and every bit of oxygen used, and then catch every bit of water and carbon dioxide coming from the lamp, and weigh them, the sum of the weights of the oil, wick, and oxygen is just the same as the sum of the weights of the carbon dioxide and water coming away.

We may then make this statement about the lamp flame. In its activity, oil and oxygen are united and changed into water and carbon dioxide. During these changes, light and heat are produced.

Now, what occurs in the lamp is exactly what takes place in the boiler of a large engine, with the difference that in the lamp we make use of the light and throw the heat away, while in the boiler we make use of the heat to expand the steam, which is made to do the work of the engine, and throw away the light.

Chemical Changes.—One other point may be noted. Oil is composed of carbon, oxygen, and hydrogen combined. Carbon dioxide is composed of carbon and oxygen, and water is composed of hydrogen and oxygen. The changes that take place in the flame are thus seen to be a rearranging of the parts of the substances which go to the flame to make the substances which come away from the flame. This kind of rearrangement of substances, in which new substances of a different nature are made from old ones, is called a *chemical change.*

Oxidation.—When the chemical change is made by oxygen uniting with something else, it is called *oxidation*, and the other substance is said to be *oxidized.*

Thus it may be said that the carbon of the lamp oil is oxidized, making carbon dioxide; the hydrogen is oxidized, forming water.

Many other examples of oxidation exist in familiar substances. Rusting of iron is the oxidation of the iron.

The Heat of Oxidations.—Whenever oxidation occurs heat is produced. If it occurs rapidly, as in the lamp, stove, or furnace, a very high temperature is produced, but if slowly, as in the rusting of iron, the heat is carried away before it accumulates in large enough amounts to make the iron warm to the touch. But even iron will burn rapidly and with a high heat and a bright light if the burning is once started in pure oxygen.

Comparison of the Body to the Lamp.—Now let us apply these ideas gained from the study of

the chemistry of the flame to the chemistry of the body.

The body is losing weight at every moment, except when we are taking food or drink. It is just like the lamp in this respect.

If we hold a cold piece of iron in front of the mouth, or against the skin, it will become covered with moisture, showing that both by the lungs and the skin water is coming away from the body.

If we catch the air breathed out from the lungs and shake it up with lime-water, the lime-water will be milky, showing that the air from the lungs contains carbon dioxide.

The body, then, is like the burning lamp again in that it is throwing off carbon dioxide and water.

The body must have food and oxygen supplies, for if they be not furnished, the body soon ceases from its activity, just as the lamp goes out.

This food must be like the oil in containing carbon, oxygen, and hydrogen at least. Indeed, much of the common food is some kind of fat or oil.

Thus, the body in one more way is like the lamp: it is plain that somewhere in the body the carbon and hydrogen of the food combine with the oxygen that comes in at the lungs.

The body is like the burning lamp in one other particular: as the result of the oxidations, it is made warm. The oxidations are not so rapid as in the flame, and, consequently, do not produce so high a temperature and make no light, but they allow motions, and in this it could be compared to the heat

of the burning lamp if it were applied in such a way as to run an engine.

The Agency of Heat.—If we examine the work done in the world, it can mostly be traced to the agency of heat.

Heat makes the currents of air which are the winds that blow our ships and wind-mills, or form the waves that beat against the shores of all lands to break them down and grind them up.

Heat lifts up the water of the ocean by evaporating it, which, carried by the winds, falls on the land, to run back again, and in its course to carve out mountains and hills and build up new land, and, as a small matter aside from this great work, to carry loads for us, or to run our machinery.

Heat from oxidations runs the many forms of engines now employed to do the vast amount of the work which is accomplished by civilized nations. The work done by the bodies of men and the lower animals comes under this rule. It is performed through the result of oxidations, and one great object of food and air is with them to have the means to carry on these oxidations.

Necessities for the Process of Growth and Repair.—In one very important way the body is not like either the lamp or the engine. It not only keeps warm and does work, but it *grows* and *repairs its own parts.*

If a lamp or engine could grow or repair its broken and worn-out parts, it is evident that we should have to supply it with more than oil and coal. Its supply would have to contain the elements of glass, brass,

iron, and of the various materials of which each is made. Further, it would have to contain other chemical substances that are necessary in making the changes in the formation of these parts.

Composition of the Body.—Every tissue of the body contains compounds of *carbon*, *hydrogen*, *oxygen*, and *nitrogen*. These compounds, with *water*, make up by far the greatest part of the body. Besides these chief substances, there exist in many of the tissues some other substances which serve particular purposes. The most conspicuous example is that of osseous tissue, which contains, as we have seen in the study of the bones, compounds of lime. In the tissues small amounts of compounds containing sulphur, phosphorus, iron, sodium, potassium, chlorine, and some other substances may be found.

All these substances must be in the food and drink, the study of which will be taken up in the next chapter. It may then be said that one other object of the food is to supply these materials for the growth and repair of the tissues.

Wastes.—This is a term which applies to the compounds which result mainly from the oxidations of the body during its work and growth. They are mainly *carbon dioxide*, *water*, and a nitrogenous substance (which is formed and excreted by the kidneys) called *urea*. They are called wastes because they can no longer be of use to the body and must be thrown away.

Questions for Review.

1. What is a machine, and how may the body be compared to one?
2. How does a burning lamp lose in its weight?
3. What else does the flame use besides oil?
4. How can this be proved?
5. What are the gases in the air?
6. What becomes of the oil and oxygen used by the lamp?
7. How can this be proved?
8. What relation exists between the oil and the oxygen on one side, and the water and carbon dioxide on the other?
9. How has this been shown?
10. What is the case with engines?
11. How do they differ from lamps in this respect?
12. What are chemical changes? Illustrate.
13. What is oxidation?
14. Give as many examples as you can.
15. What of the heat from oxidations?
16. Does rusting of iron produce heat?
17. In what ways is the body constantly losing weight?
18. Show this to be the case.
19. How does the body compare with the lamp in the supplies demanded?
20. How does it compare with it in the matter of heat?
21. What are the sources of heat and power of doing work in the body?
22. What are some of the things which heat accomplishes in the world?

23. What is one of the principal objects of taking food and air?

24. In what very important particular do the bodies of animals differ from the lamp and from engines?

25. What are the main elements in the body?

26. Name others that occur.

27. What is one other object of food?

28. What is meant by the term wastes?

29. What are the chief wastes of the body?

CHAPTER IX.

FOODS.

The Forms of Food, as we see them brought to the table, are mixtures of certain substances, some of which occur in many different foods. For example, sugar is naturally in the fruits, and is often added to other foods in their preparation. Again, starch is present in the bread, in the potatoes, in the pudding, and in the pie. Fat or oil may occur in several foods, either naturally, as in the meats, or by its use in cooking.

Kinds of Food Substances.—For convenience in study these foods are put into groups which may be called *the food groups.* The food substances—that is, the substances which make up the foods that are placed on the table—are of two general classes, *organic* and the *inorganic.*

The Organic Food Substances are those which are derived from plants and animals, and make up most of the food we take. Among these substances those most alike in their composition are put together into groups.

The Starch and Sugar Group.—Chemists have found that the different kinds of starches and sugars are all composed of the same elements, and are alike in many other ways. Indeed, starch can be

changed into sugar. Gums, such as gum arabic, belong to the same group. These substances are all composed of carbon, hydrogen, and oxygen.

The starches are derived from plants, and are especially abundant in all grains and seeds used for food. They occur also in the leaves, stems, and roots of plants, as in cabbage, lettuce, potatoes, and sweet potatoes. Sugars are usually obtained from plants, but one kind is found in milk. They are found in ripe fruits, and, indeed, may be in any part of the plant.

In the plant the starch is often changed to sugar, as is seen in the change from a green to a ripe apple. Man has learned how to accomplish this change, and every year large quantities of starch are made into sugar for the market. Gums form but an unimportant part of the food.

The Group of Fats.—This group includes the various fats and oils found in milk, in the flesh of animals, and in plants. The words fats and oils are simply relative terms, fats being applied to those of the group which are solid at an ordinary temperature, of which tallow is an example, while oil is a liquid at the same temperature, such as olive oil.

These substances, like the starch and sugar group, are composed of carbon, hydrogen, and oxygen. Although composed of the same substances, they differ from the starch and sugars very much.

The Group of Proteids.—A third group of organic food substances consists of a number of substances very common in the different forms of food, but since they are not commonly separated from

them, as are starch, sugar, and fat, they are not familiar substances. The most familiar example of this group is the white of an egg. This is mainly *egg-albumen*, with a large amount of water.

Most of the other members of the group of proteids, if they could be separated from the substances which contain them, would look and act very much like the albumen of the white of an egg. For example, they would coagulate when heated, and act in other ways which lead chemists to recognize them as similar.

One such substance is in milk, and makes the main part of cheese. It is *casein*. One is found in the muscle substance, and is known as *myosin;* one in the blood, *serum albumen;* one in such seeds as peas and beans, called *legumen;* one is found in many grains, called *gluten*. It forms the sticky part of wet flour.

There are many other proteids, but those just given will serve as examples, and are, indeed, the main ones that occur in our foods. The proteids all contain carbon, hydrogen, oxygen, and nitrogen.

It may be observed that the last group given contains one element not in either of the other groups —that is, nitrogen. From this fact the proteids are sometimes called *nitrogenous foods*, and the fats, starches, and sugars are called the *non-nitrogenous foods*. Some plants can manufacture all the different kinds of food substances from the soil, water, and air. Animals can not do this, but must have the proteids, fats, sugars, and starches already made for them. Consequently, they must take for food either

such substances as a plant has produced, or the tissues of some animal which has eaten the plant.

All animals live by the death of other organisms, man being no exception. There are many plants like animals in this respect. They are those which do not possess the green color found in leaves, which is called *chlorophyll*, and, consequently, they can not live on inorganic foods. The mushrooms, molds, mildews, and many forms of parasitic plants—that is, plants that live on the substance of other plants—are examples. All the plants without chlorophyll must have for their food some organic substance.

Table of the Food Substances.—The following table shows these classes of foods at one view:

- FOODS.
  - Organic
    - Proteids (Egg-albumen, Casein, Gluten, Myosin, Legumen,) contain C, O, H, and N.
    - Fats contain C, O, and H.
    - Starches and Sugars contain C, O, and H.
  - Inorganic
    - Water.
    - Salines.

Relation of the Foods to the Body.—If the facts of the preceding chapter in regard to the chemistry of the body be recalled, we may see from the above table that the fats, starches, and sugars are composed of the same elements as the oil in the lamp.

They can be oxidized with just the same results as occurred in oxidizing the oil—that is, the production of water and carbon dioxide, together with the formation of heat.

This is no less true of the proteids, with the exception that in burning them, in addition to water and carbon dioxide, some substance containing nitrogen is given off.

We could burn meat, bread, eggs, peas, beans, and the various grains in the furnace of a boiler and get sufficient heat to run the engine. We have already seen that they are oxidized in the body with the same results.

It may be noticed further that only one group of foods, the proteids, contains nitrogen. As nitrogen forms a part of every tissue in the body, it is very evident that some foods of the nitrogenous group must be taken. If only foods containing substances belonging to the other groups were used, starvation would result.

It will be seen that all the food groups contain elements which enter into the tissues, and, no doubt, they all help to form them.

The Inorganic Foods.—This division includes water and various mineral substances, of which the greatest amount taken is common salt. The others are taken in very small amounts mixed with the other foods. These substances, called salines, are the same as those mentioned as being in the tissues of the body. They are compounds of lime, magnesium, sodium, and potassium. They are absorbed by the plants from the soil, and from this source we obtain them, either directly from the plants, or indirectly through the flesh of animals which have fed on them.

The Use of Inorganic Foods.—Plants which

have the green substance in them which gives them their well-known color are the only ones of the living organisms which can live and grow on purely mineral food substances. Still, the body makes some use of them. From the inorganic group of foods the tissues obtain their supplies of the mineral substances used in their structure, but none of these can be oxidized, and hence can not be the source of heat or motion.

Water, the principal one of the inorganic foods, is also one of the most important. Its use is to form solutions so that the liquid blood and lymph may be possible, and that the tissues may make the exchanges by its means with the blood. All the processes of the body depend on the presence of water. The tissues might be said to live on substances dissolved in water. A slight reduction of this water causes a severe thirst, which drives us to make good the loss.

The Proportion of the Different Foods needed in the Body.—To accomplish the three main purposes of foods—viz.: to keep the body warm, to furnish it means to perform its work, and to furnish it with material for growth—it is evident that there might be a combination of food substances that would have the best proportions.

What these proportions are has been the subject of much investigation. It has been shown that if too much nitrogenous foods be taken, the labor of the body is greatly increased in getting rid of the extra amount. If this is continued for a considerable length of time, serious diseases are sure to follow.

The right proportion of the non-nitrogenous foods to the nitrogenous is said to be about four parts of

the first to one of the second. These proportions are about those in milk, or in wheat flour when in the form of "Graham flour."

Meats, peas, and beans, when taken alone, have more than the needed nitrogen, while rice and potatoes do not have enough. As our food is served to us, we have various groups which are likely to give us enough of each kind.

One's appetite, if he is in good health, will guide him in the matter by making a demand for the kind of food wanting, and giving a distaste for that of which too much has been taken.

This is the body's method of regulating this extremely important matter, and it should never be abused by eating when one feels that he does not need food. This guide may be relied upon as a safe one to those who have not disturbed its healthy action by eating things simply to please the taste. The healthy action of this guide must be preserved.

Alcohol as a Food.—It has often been questioned whether alcohol can act as a food; that is to say, whether it can be oxidized in the body, and may thus furnish physical energy, or serve some other useful purpose. The question is one to which no positive answer can be given, since, as yet, it has not been definitely decided. But even if it were demonstrated that alcohol could serve as nourishment, the injurious effects it has on the body would outbalance any value it might have as a food. Furthermore, alcoholic drinks are made at great expense of good food substances, so that their manufacture destroys far more food than they can ever supply.

Questions for Review.

1. What is said of the composition of common foods?
2. Illustrate how one substance may be found in many forms of foods.
3. What are the two general divisions of food substances?
4. What are organic food substances?
5. What is said of starches and sugars?
6. Of what elements are they composed?
7. Where are they found?
8. What relation has starch to sugar in the plant?
9. What is said of the gums?
10. What constitutes the group of fats?
11. From what are they derived?
12. Give several foods that would furnish some of them.
13. What is their composition?
14. What are proteids?
15. Give some familiar example.
16. In what are they alike?
17. What are the chief proteids of the foods?
18. Name the source of each given.
19. What is the composition of proteids?
20. Which are the nitrogenous foods, and which the non-nitrogenous?
21. What are the inorganic foods?
22. What is their source?
23. Name some of the principal ones.
24. What plants furnish animals all the organic substances?

25. What kinds of food do they live on?
26. What kinds of food must animals have?
27. What plants are like animals in this respect?
28. Write out the table of food substances.
29. What foods can be oxidized?
30. What results would follow the oxidation of each?
31. How could this be shown?
32. What is said of the necessity of the nitrogenous group?
33. What is the use of the inorganic foods?
34. What is the use of water?
35. Why would one group of foods not answer the needs of the body?
36. What is the best way to mix them?
37. What proportion is given as the best?
38. What foods answer the requirement?
39. What is the objection to a meat diet alone? To a diet of rice alone?
40. What is the body's manner of selecting the proper kinds and amounts?
41. When may this be taken as a safe guide?

CHAPTER X.

ANATOMY OF THE DIGESTIVE SYSTEM.

Digestion.—It has already been pointed out that the tissues live on the blood, and that the serum of the blood is kept up in quantity by food and drink.

But every one knows that blood and food are two very different things. Much of the food is of solid material and will not dissolve in water. To get into the blood vessels it must pass through the lining of the stomach or intestines. This process is called *absorption.*

After the food is dissolved and brought by the current of blood to the capillaries in the tissues, it must again pass through a membrane, the coat of the capillaries.

All this is only possible when the food is in a liquid form. Beans, meat, bread, potatoes, whatever the form of the food, that part which is to be food for the tissues must be dissolved. It is the object of digestion to *reduce food to a liquid form.*

Foods that require Digestion.—The sugar is readily soluble in water and is usually already dissolved in the food or drink that we take, and, consequently, needs no further action that it may be absorbed into the body. But of starch and the proteids, none of those taken as foods can dissolve in

water sufficiently for this purpose, most of them not at all.

The oils, it is true, are in a liquid form, and the fats will be melted to a liquid form by the heat of the body, but still they will not soak through the membranes in their ordinary form. They must also be specially prepared before this can take place.

The water remains unchanged, being absorbed as water, passing anywhere in the body, and being thrown out of the body as water.

The mineral substances taken in the food are in minute quantities already dissolved, and, of course, need no digestive action.

It may be said, then, that of the foods, the proteids, the fats and oils, and the starches and the gums, must be digested.

How is Digestion Accomplished ?—The foods are digested by being taken into the alimentary canal, where at various portions they have mixed with them certain liquids which will change the food substances so that they become liquids ; then the food substances in liquid form are absorbed and brought into the blood.

The Alimentary Canal.—The alimentary canal is a tube about thirty feet in length, passing through the body, into which the food is placed to be subjected to the liquids which make these changes in the foods. It is variously modified along its course into different parts which perform different actions.

All these parts, together with the organs connected with them which form the digestive liquids, are called the *digestive system*. The digestive system consists

of the *mouth* and the *salivary glands*, the *pharynx*, the *œsophagus*, the *stomach*, the *small intestine*, with the *liver* and the *pancreas*, and the *large intestine.*

Glands.—The essential part of digestion is accomplished by liquids poured upon the foods. These liquids are formed by organs called glands. Glands are also used in other parts of the body to form liquids, as, for example, to form sweat and tears.

Very simple forms of glands are very minute tubes or sacs, which are surrounded by a network of capillaries. The lining of a gland forms the liquid peculiar to it, which is called its secretion. This flows out of the mouth of the tube. The gland tissue gets from the blood near it the material from which it forms its secretion.

In large glands, the tubes are divided into very many branches, so that the gland comes to be in form like a tree with its branches, except that the branches are crowded and folded together in a somewhat solid form.

The divisions of the parts of the tubes greatly increase the secreting surface of the gland. In all the branching a network of capillaries follows each minute branch. A simple tube or sac is a *simple gland*, while a gland consisting of branched parts is a *compound gland.*

The Mouth.—This part of the system can be so well studied from a view of the object itself that such a view and not a printed description should be relied upon for a knowledge of its parts, except it be to learn the names of the parts.

The mouth forms a cavity, which, when closed, is

well filled by the tongue and the teeth projecting into it. It has very movable walls at the front and sides in the lips and cheeks, whose middle layers contain many muscles which produce their great number of motions.

The tongue projecting from the floor of the mouth is extremely movable. The roof, the *palate*, is hard forwards, and soft at the back, ending in a curtain which hangs down to make the posterior wall of the mouth. The two curved rows of teeth just strike each other.

Besides the motions of the lips, cheeks, and tongue, the whole lower part of the mouth can be moved up and down, from side to side, and from front to back, by the muscles that move the lower jaw.

Determine from your own mouth what these motions are and where the muscles are placed that produce them.

Placed in the surface of the tongue are the little organs of taste. In the walls of the mouth everywhere are little glands which secrete mucus, the liquid which, mixed with the secretion of the salivary glands, is the one which we know as constantly in the mouth. The salivary glands empty their secretion into the mouth.

The Teeth.—The position and characteristic forms of the teeth can be plainly made out in one's own mouth by the use of a mirror. Fig. 28 of the teeth in the lower jaw shows how they are set in the bone. The teeth appear in two sets. They are ten in each jaw of the first set, which appears in childhood, and sixteen in each jaw of the adult. The four front

teeth in each jaw are called *incisors;* the next one on each side is a *canine;* the next two, the *premolars;* and the last three are the *molars.* The same teeth occur in many animals and in the same order, but not always of the same number. They are in them much varied in form to adapt them to the many uses that their owners make of them. Very many of them use their teeth for other purposes besides that of chewing.

Fig. 28.

LOWER JAW-BONE WITH THE TEETH.

Structure of a Tooth.—Fig. 29 shows the internal view of a tooth cut through from the top or crown to the tips of the roots. It shows it to consist of three substances: A layer of *enamel* (1) over the crown; a layer of *cement*, which is of the same structure as bone, around the roots; these lie on the main substance of the tooth, the *dentine*, or ivory (2).

These are very hard substances, the enamel being the hardest. In the center of the tooth the hollow space is filled with blood vessels, nerves, and connective tissue. They come in at the points of the roots. These together are called the pulp.

Mastication.—The mouth has other uses besides its action on the foods, the chief one of which is that of speaking. Its work with the foods is to crush and divide them that they may be swallowed first, and afterward may be moved along the remainder of the

alimentary canal to be acted upon by the digestive liquids. The process is known as *mastication.*

If one will take a portion of food into his mouth and proceed to masticate it, and at the same time note the action of the tongue, lips, cheeks, lower jaw, and teeth, he will learn how deftly the food is handled by them, being first taken to one part of the mouth, then to another. All the hard portions are brought between the teeth, where they are crushed. In the meantime it is mixed with saliva until it is formed into a ball, when it is, by a quick motion of the tongue against the roof of the mouth, shot into the next division of the alimentary canal, the pharynx.

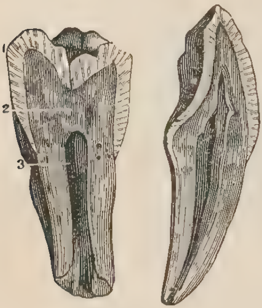

Fig. 29.

STRUCTURE OF A TOOTH.

1, enamel; 2, dentine; 3, pulp cavity.

The Saliva.—The saliva has very important uses. In the first place, it allows dry food to be swallowed. It dissolves the food so that it may be tasted. It and the mucus moisten the lining of the mouth and the larynx, and thus make the motions of speech possible.

It has also the power to digest the starch. It does this by changing it into sugar. The food is in the mouth so short a time that this action of the saliva does not seem to be a very important one. The starch is mainly digested in another place, as we shall see.

The Salivary Glands.— The salivary glands are

arranged in three pairs: one pair in the sides of the face, just in front of the ears, the *parotid glands;* one pair by the angles of the lower jaw, the *submaxillary*, and one near the tongue, the *sublingual.*

Hygiene of the Mouth.—The mouth should be kept as clean as possible. The arrangement of the teeth is such that particles of the food are sure to become lodged around them. These kept at the warm temperature of the mouth will decay, and in the process form substances which corrode the substance of the teeth, leading to their decay and final loss, often with great suffering. In very many such cases these troubles might be avoided by constant cleanliness.

The mouth should be especially well cleansed after the evening meal, so that particles of food should not be left undisturbed on the teeth for so long a time. Whenever a tooth shows signs of decay, it should be promptly attended to by a dentist, as in such a case the great majority of ailing teeth may be saved.

A decayed tooth may be the source of greater danger than its pain and final loss. It and any other form of sore or wound in the mouth may become the points of introduction for germs of disease.

Questions for Review.

1. In what does digestion consist?

2. What is the reason that digestion must take place?

3. What foods do not require digestion?

4. What foods require digestion?

5. What of the fats and oils?

6. How is it with the water? With the mineral substances?

7. What in general terms is the process of digestion?

8. What is the alimentary canal?

9. What constitutes the digestive system?

10. What are glands?

11. What are simple forms of glands?

12. What is a secretion?

13. How is the increase in the secreting surface in the gland brought about?

14. What is such a gland called?

15. What is said of the manner of studying the mouth?

16. Describe the mouth.

17. What motions are possible in the mouth?

18. What secretions come into the mouth?

19. Describe the teeth, giving the names, forms, and positions of each.

20. What of the teeth of the lower animals?

21. Describe with a diagram the structure of a tooth.

22. What is mastication?

23. Describe its processes.

24. What are its uses?

25. How is the food passed to the pharynx?

26. What are the uses of the saliva?

27. Which, as you regard it, is the most important, and what reasons can you give for the view?

28. Where does the saliva come from?

29 Give the location and names of the glands.

30. What is said of the care of the mouth and teeth?

CHAPTER XI.

DIGESTION.

The Pharynx.—Just beyond the mouth the alimentary tube becomes the *pharynx*. There are several openings into this portion — one from the mouth, one from each nostril, one from each middle ear, one into the larynx, the organ where the voice is produced; and the opening into the next division of the alimentary canal, the *œsophagus*.

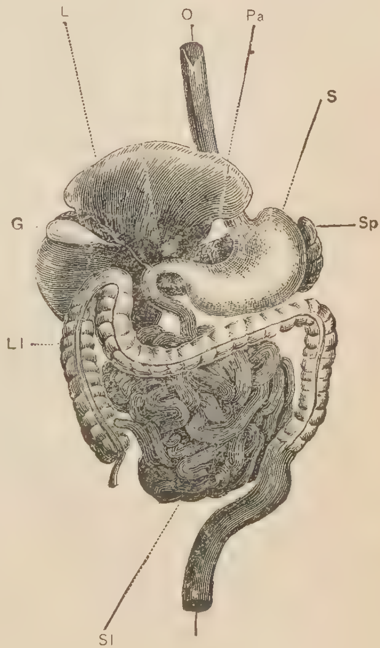

Fig. 30.

General View of the Alimentary Canal.

O, œsophagus; *S*, stomach; *SI*, small intestine; *LI*, large intestine; *Sp*, spleen; *L*, liver (raised up); *G*, gall bladder: *Pa*, pancreas.

The Œsophagus. — This is the portion of the alimentary canal which extends from the pharynx to the stomach. It is eight or nine inches in length. It and the pharynx are lined internally with

a mucous membrane. Outside of this are the muscular walls.

Swallowing.—The food is sent forcibly from the mouth into the pharynx. The pharynx acts something like a funnel over the top of the œsophagus. When the food is in the pharynx, its muscular walls close around it and quickly push it into the œsophagus, where portions of the circular bands of muscles relax before the food, and others contract behind it to push it on into the stomach. Water is served exactly in the same way, and both water and food can be swallowed up as well as down.

The Stomach.—This organ is a part of the alimentary canal more dilated than the other portions, and so arranged as to retain the food in it a certain length of time. (Fig. 31.)

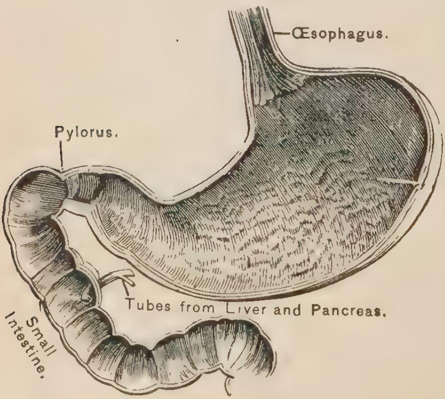

Fig. 31.
SECTION OF THE STOMACH.

It is in the upper part of the abdominal cavity somewhat to the left side. The opening at the point where the œsophagus joins it is called the *cardiac* opening; the one at the opposite end, where the small intestine joins it, is called the *pylorus*.

In this latter place the muscular walls form a ring, which remains contracted some time after a meal is taken, opening and closing from time to time to allow liquids to pass, thus retaining the more solid portions for the digestion which takes place in the stomach. It finally relaxes and allows all the contents to pass on to the small intestine.

The walls of the stomach have four layers: the outer the *peritoneum;* the next, a *muscular* layer; the next, a *connective-tissue* coat; and the inner, the *mucous coat*.

Digestion in the Stomach.—The mucous coat of the stomach is filled with small glands which secrete a liquid known as *gastric juice*. During the presence of food in the stomach, this liquid is poured out on it in considerable quantities.

Gastric juice affects only one of the food groups, the proteids. When these food substances are kept with gastric juice a certain length of time, they are changed into soluble forms of proteids called *peptones*. This change takes place slowly. To cause the gastric juice to become thoroughly mixed with the food, the muscular walls of the stomach, by contracting in many different directions, push it around, backward, and forward many times.

Absorption from the Stomach.—A very great number of capillary blood vessels forms a close network in the mucous coat immediately next to its surface. This arrangement brings the blood so near the liquid in the stomach that nothing but a very thin wall of membrane lies between them. This allows the liquid contents of the stomach and

what may be dissolved in it to soak through to the blood.

Besides these blood vessels, there are also the lymphatics, arranged in the same position, so that they may also receive liquids from the stomach.

The process by which a liquid may pass into either of these vessels is called *absorption*. The rapidity with which it occurs is shown by the quick effect which some medicines have on the body when taken into the stomach.

The Small Intestine.—The small intestine is a

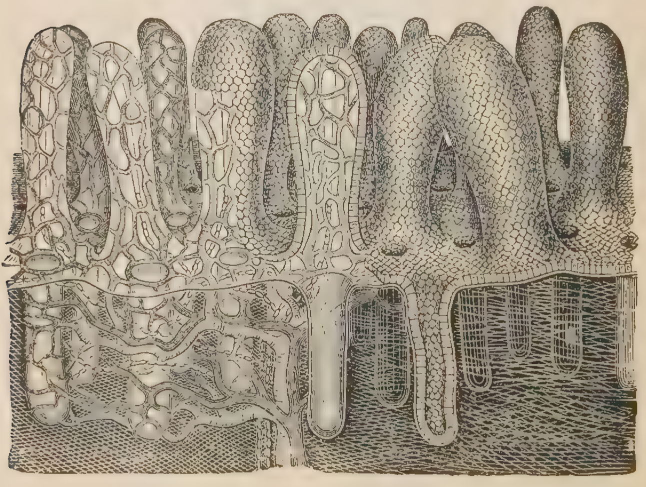

Fig. 32.

SECTION OF THE MUCOUS COAT OF THE SMALL INTESTINE. DIAGRAMMATIC.

Some of the villi have their covering layer removed to show the structure. The tubes are intestinal glands.

much narrower tube than the stomach. It is about twenty feet in length. It is suspended from the

margin of a membrane called the *mesentery*, the inner edge of which is gathered together in one place and fastened to the back of the abdominal cavity.

The coats of the small intestine are exactly the same in name and arrangement as those of the stomach. But the mucous coat differs from the same coat of the stomach in being densely covered with minute projections.

These are shown very much enlarged in Fig. 32. They are the *villi.* They are special arrangements for absorption. Each one has in it, as shown in the figure, a network of capillary blood vessels, and another kind of small vessels called the *lacteals*, but they are really lymphatics, and, with many of the lymphatics, they empty into the thoracic duct. Over each villus is a very thin layer of tissue, which allows digested food substances to pass through either to the blood vessels or the lacteals, from which it soon enters the general circulation.

Secretions coming into the Small Intestine.—The mucous coat has in it besides the villi a few compound glands in the upper portion, and a very great number of simple glands in the lower (seen also in the figure), which secrete *the intestinal juice.*

The *pancreas* is a large gland lying just behind the stomach, which forms the *pancreatic juice*, and pours it into the small intestine by its duct, which empties into the small intestine a short distance below the pylorus.

The Liver.—The liver is a very large gland, placed just under the diaphragm, mainly on the right side. It empties its secretion, the bile, into the small intes-

tine at a point very near the opening of the pancreatic duct. The pancreatic juice and bile are immediately mixed with each other and with the food.

Digestion in the Small Intestine.—The digestion which goes on in the small intestine may be considered as the most important of all, since the pancreatic juice acts with energy on proteids to change them into the soluble peptones; on the starches to change them into sugar, and on the fats to change them into a state in which their particles are extremely minute, small enough to find their way through the thin layer over the villi. Some of the fats are also changed into substances which will dissolve.

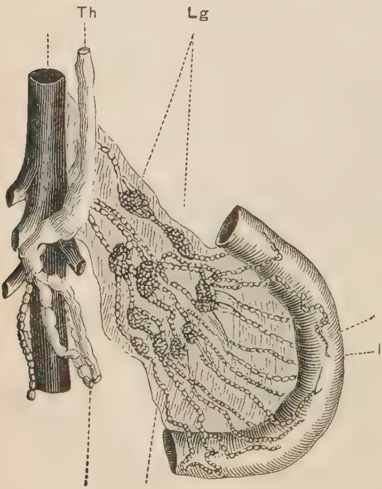

Fig. 33.

LACTEALS.

Showing the connection of the small intestine to the thoracic duct by the lacteals lying in the mesentery. Th. thoracic duct.

The Bile.—This liquid comes in very large amounts into the intestine during digestion.

It has been shown to have very slight direct digestive action on any of the foods, but it is known to aid the process of digestion in various ways. Among them may be mentioned that the bile makes the contents of the intestine *alkaline*, which is necessary

to the action of the pancreatic juice, and that it in some way aids in the absorption of the fats.

It has probably many other uses, as it is a very complex liquid. Our ordinary foods contain a considerable amount of substances which are not acted on by any of these fluids, termed indigestible parts.

These are, by the constant motions of the small intestine, sent along to accumulate in the large intestine. They move more and more slowly as they pass along, that the last amount of digested food may be absorbed before these substances are removed from the body.

Absorption.—As already mentioned, absorption may take place from the stomach and from the small and large intestines. It is mainly from the small intestine. The food, after being absorbed, may reach the heart, and from it the general circulation, by two different courses:

1st. That which is taken up by the blood vessels goes by the portal vein to the liver, through the capillaries of the liver to the hepatic vein in the liver, into the inferior vena cava, and thence to the heart.

2d. That which is taken up by the lacteals passes on to the thoracic duct, Fig. 33, from which it empties into the left subclavian vein, and from this it soon reaches the superior vena cava.

These two courses will be made clear by consulting the diagram of the circulation of the blood, given in the chapter on Circulation.

Conclusion.—In a former section it was said that the food of the tissues is the blood. We have now

seen one source from which the food is constantly added to the blood. It is placed in parts of a vessel, the alimentary canal, and at different places the liquids change different members of the food groups into solutions. These are given in the following table:

1. *Saliva* acts slightly on the Starches.
2. *Gastric Juice* acts on the Proteids.
3. *Pancreatic Juice* acts on the { Starches. Fats. Proteids.

These made soluble and the sugar already dissolved include all the principal foods.

Questions for Review.

1. Give the position and description of the pharynx.
2. With what is it connected?
3. Describe the œsophagus.
4. How is swallowing accomplished?
5. What is the stomach?
6. Where is it placed?
7. Describe it.
8. What is the action of the pylorus?
9. What are the coats of the stomach, and what is their arrangement?
10. What liquid is secreted in the mucous coat of the stomach?
11. What food substances does it dissolve?
12. What are the motions of the stomach?
13. What is absorption?
14. How is it accomplished at the stomach?

15. What of the rapidity of the process?
16. Describe the small intestine.
17. What of its coats?
18. Describe a villus, giving its internal structure.
19. What is its use?
20. What secretion is furnished by the mucous coat of the small intestine?
21. What other secretions come into the small intestine, and at what point?
22. Give the position of the pancreas.
23. Describe the position of the liver.
24. Upon what food substances does the pancreatic juice act?
25. What of its importance?
26. What are some of the uses of the bile?
27. What are the chief places at which the foods are absorbed?
28. What are the two ways by which it is absorbed?
29. What is the exact course of the food to the heart when taken up by each of these?
30. Give the general conclusions in regard to the digestive process.

CHAPTER XII.

RESPIRATION.

What Respiration Accomplishes.—It has been shown in a former lesson that not only does the blood bring food and drink to the tissues, but it also brings air to them; or, more correctly, that part of the air which they need, the *oxygen*. It was also shown that the blood removes from the tissues certain substances which were formed in them through their activity. They are the so-called "*wastes.*" One mentioned was carbon dioxide.

These, in the air, are free gases; in the blood they are dissolved. As the parts of the alimentary canal are the places of introduction of food and drink into the blood, so the lungs are the place at which oxygen is introduced into the blood, and carbon dioxide is removed from it.

Respiration has for its purpose the bringing of the air to the blood, so that these changes may take place between the two. To speak accurately, the tissues carry on respiration between themselves and the blood when they take oxygen from the blood and give up carbon dioxide to it. This has been called *internal respiration*, while that at the lungs is the *external respiration*.

These are good terms, as they express the facts, but

for convenience we will use the term respiration in its common meaning, which is to represent external respiration.

The Respiratory Apparatus.—The essential part

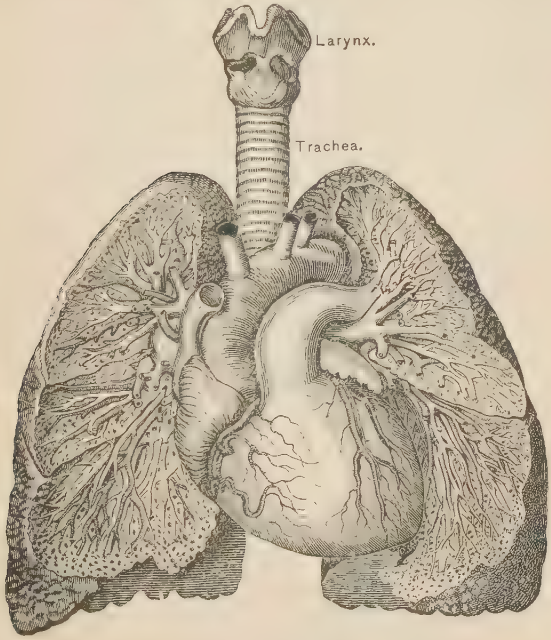

Fig. 34.

THE HEART AND LUNGS.

of the breathing apparatus is a thin membrane, so arranged that the oxygen can come on one side and the blood on the other. In such a case the oxygen can pass into the blood and the carbon dioxide out.

In the lower animals, the breathing apparatus is found in many different forms. The gills of a fish

are familiar to all. In all these forms, as different as they may be in other regards, they all have the essential arrangement spoken of above. The oxygen is always either in the air, mixed with the other gases before given, or it is dissolved in the water which has obtained it from the air.

In the gills of the fish the delicate fringes are so many projections of very thin skin, through the core of which the blood circulates, but on the outside the water with the dissolved oxygen is made to pass. In the lungs of a man there are immense numbers of little thin-walled sacs, into the centers of which the air comes, and around the surface of which the blood circulates. The rest of the apparatus is to pump the air in and out of the passages which are connected with these little air sacs, so that there may be a constant change of the air.

The Respiratory Organs.—The part of the apparatus which accomplishes this constant removal of the air consists of the thorax and the lungs, which hang as two sacs in its cavity, and the tubes in the lungs, and the large ones which connect them with the outer air.

If we name the air passages in order from without, they are the *nostrils* and the *mouth*, the *pharynx*, the *larynx*, the *trachea*, its two large branches, the *bronchi*, and their numerous branches, the *bronchial tubes*, which become so small in their subdivisions as to require the microscope to see them. These end in groups of minute *air sacs*, mentioned above. They are microscopic.

A group of these air sacs, or vesicles, is shown in

Figure 35. Among these are close networks of pulmonary capillaries.

Structure of Air Tubes.—The trachea, bronchi and bronchial tubes have a framework of cartilaginous rings, which hold them open on all sides. The rings have connective tissue between them and around them. The lining of the passage is mucous membrane, in which is a large number of mucous glands, whose secretion is constantly forming.

Fig. 35.

AIR VESICLES.

1, last division of bronchial tube; 2, air vesicles, magnified.

The mucus is made to flow toward the throat by means of very minute projections, seen only with higher powers of the microscope, which are on the surface of the mucous membrane. These are the *cilia*. They keep up a constant waving motion, which carries the mucus along, together with dust which settles on it from the air.

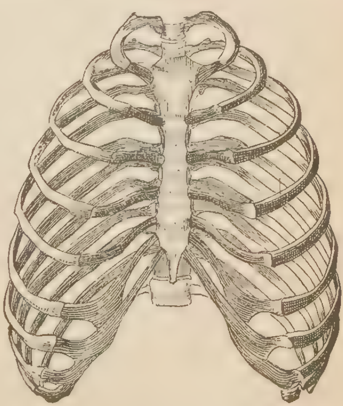

Fig. 36.

BONY WALLS OF THE THORAX.

The Thorax.—The lungs are suspended in the cavity of the thorax. The bony support of the thorax is shown in Fig. 36, and consists of the dorsal verte-

bræ, the ribs, and the sternum. In this framework, while the ribs are attached at their extremities, their middle portion can be moved up and down by muscles between them and those attached to them from above and below. The muscular partition between the abdomen and the thorax, the *diaphragm*, forms the bottom of the thorax.

The Respiratory Acts.—Respiration consists of two acts: *inspiration*, by which an amount of air is brought into the lungs, and *expiration*, by which about the same amount is expelled. The lungs hang in the thorax as elastic sacs in air-tight cavities. The pressure of the air, which is fifteen pounds to the square inch, nothing but a little liquid being between their outer walls and the walls of the thorax, swells the lungs out against these walls.

If now the walls of the thorax are pulled away a little more, the pressure of the air on the inside of the lungs makes them follow the retreating walls of the thorax. On the other hand, by the walls of the thorax pressing upon the lungs they are emptied to the same extent.

Inspiration.—In inspiration the cavity is enlarged. This is accomplished in two ways: First, the diaphragm being curved upward pulls itself down by contraction. Second, by the contraction of one set of the muscles between the ribs (the external intercostals) the ribs are raised, which motion, from the way they are attached (see Figs. 37 and 38), throws them out.

Expiration.—This act consists in making the cavity of the thorax smaller. This is done in two ways:

First, by the muscles of the walls of the abdomen, contracting and pressing upon the contents of the abdomen, and thus forcing the diaphragm up again.

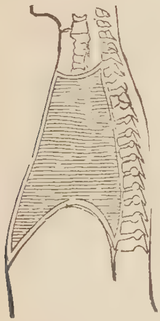

Fig. 37.

THORAX IN EXPIRATION.

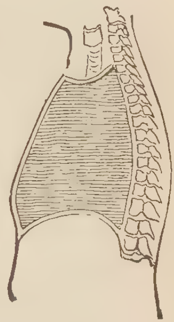

Fig. 38.

THORAX IN INSPIRATION.

Second, by the other set of intercostals (the internal) contracting to pull the ribs down. In both acts many other muscles may take part which can not be discussed here.

Nervous Control.—These motions are regulated by nerves, so that one follows the other in the proper succession, frequency, and strength, each of which varies much with the varying activity of the body. For, the more work done the greater must be the supply of oxygen, and the greater the amount of carbon dioxide to be got rid of.

These actions are involuntary, yet the will may modify them, as it does in the act of speaking. Ordinary respirations average about seventeen a minute.

One will be profited if he will study in himself or

another how this rate will vary, as well as the character of the act, by various kinds and degrees of exercise. Sighing, crying, laughing, coughing, sneezing—all are modifications of the respiratory actions, the character of each of which let the pupil study from the actions themselves.

Changes in the Respiration.—In the study of the chapter on the chemistry of the body, the experiment showed that when air came from the lungs it had in it an increased amount of water and carbon dioxide. It also has less oxygen and is warmer. Besides these changes, air from the lungs contains certain organic substances, which are very small in amount and can not be obtained in sufficient quantity to be weighed.

They are easily detected by the sense of smell when one passes from the open air into a poorly ventilated room in which there is a number of people.

From these causes, air once breathed is not fit to breathe again. There is not enough oxygen in it, and these organic substances seem to be real poisons.

Amount of Air breathed.—The lungs of an adult contain about one gallon of air. In an ordinary expiration only about one pint of air is thrown out. This can be shown by breathing through a tube passing under the mouth of a bottle filled with water, and inverted over water in such a way as to catch the air breathed out.

The amount of air breathed into the lungs is about the same. It can easily be seen that a pint of air would only fill the trachea and the upper air passages.

How the Oxygen is brought to the Air Cells.—Gases have the power to freely pass into each other. This property is called diffusion. If a pint each of a dozen gases were put in different parts of a close room, in a short time they would be equally distributed throughout the room.

By this property, the oxygen that is in the upper part of the lungs diffuses through the rest of the air to the air vesicles, and the carbon dioxide diffuses out to the upper part, where the acts of breathing remove the old air and bring in the new.

Changes in the Blood.—Once in the air vesicles, the oxygen passes through the very thin membrane of their walls and the walls of the capillaries into the serum, where it is taken up by the red corpuscles, which, by the current of the blood, are carried to the tissues, where the corpuscles give up the oxygen, and it passes to the tissues.

The carbon dioxide, on the other hand, passes from the tissues to the blood, which sweeps it around to the lungs, where it escapes. The water is also continually escaping at the lungs.

Thus, the organs of respiration and of circulation are made the mediums of exchange between the outside air and the tissues far removed from them.

Ventilation.—The tissues demand a constant supply of oxygen. If this supply is cut off for a very few minutes, death will follow. If in any way restricted or interfered with, more or less serious results will follow. It can not be too strongly emphasized that the body must be surrounded with an abundant supply of good air.

When one is engaged in in-door employment, it has been estimated on carefully obtained facts that each one should have at least three thousand cubic feet of space to himself, with a constant supply and removal of air. This space would be about the amount in a room fifteen feet long by fifteen wide, with the ceiling twelve feet high.

If less space is used, special care should be taken to secure perfect ventilation. It should also be remembered that every lamp or gas flame in the room is using up large quantities of oxygen, and pouring into the room large quantities of carbon dioxide.

In respired air it is found that the most injurious part is the small amount of organic substances that is given off. Besides being ventilated, living and sleeping apartments must also be kept clean.

Other Dangers in the Air.—Besides the things from the lungs themselves, other substances may occur in the air, which, reaching the lungs, may find through them an entrance into the body and become the causes of disease; or these foreign substances may even be direct poisons, as in the case of some gases.

Such substances are known to arise from sewers or unclean cellars, streets, or yards. All such places should be watched, that filthy accumulations may not be the sources of these evils. It has been clearly demonstrated that unclean houses and streets are dangerous.

It seems possible to live in such surroundings for a while in health, but in them one is in constant danger, and those in such localities suffer most from

epidemic diseases. One should not dress in a manner to interfere with the respiration or circulation.

The Voice.—Vocal sounds are produced in the larynx by the air passing between the parallel edges of two folds of the lining membrane of that organ. These folds are the vocal cords, and are tightly stretched and close together at the time of the sound, but are relaxed and fall apart at other times.

The Larynx.—The larynx, Fig. 39, placed on the

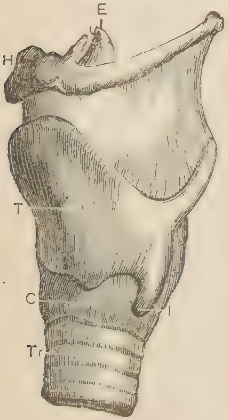

Fig. 39.

LARYNX—SIDE VIEW.

T, thyroid cartilage; *C*, cricoid cartilage; *Tr*, trachea; *H*, hyoid bone; *E*, epiglottis; *I*, joint of thyroid cartilage.

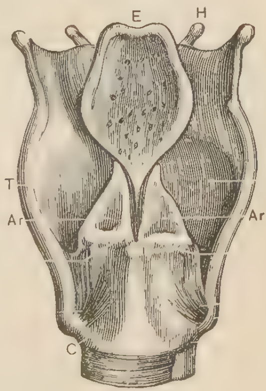

Fig. 40.

LARYNX, BACK VIEW.

Ar, arytenoid cartilages. The other letters the same as in the preceding figure.

top of the trachea, consists of a box formed of a frame of cartilaginous plates, some of which can be moved on the others by a number of muscles.

The largest of these cartilages, the *thyroid* (see the figure), forms the projection in the neck known

as "Adam's Apple." It rests on a ring-like base, the *cricoid cartilage.*

The vocal cords are attached to small cartilages at the back called the *arytenoid*, and to the thyroid in front. By the movements of these cartilages the membranes of the vocal cords are stretched and brought together, or separated.

The sound is produced by the air passing these in a stretched condition and with their edges close together. Fig. 41 shows the ligaments and the cords with the covering membrane removed. The sounds of the letters are made to differ from each other by giving different shapes to the mouth, pharynx, and larynx.

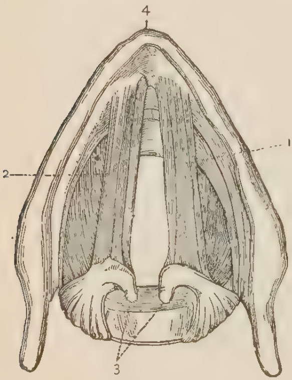

Fig. 41.

LIGAMENTS OF THE VOCAL CORDS.

(1 and 2), the ligatures; 3, arytenoid cartilages; 4, thyroid cartilage.

The *epiglottis* is a lid which is made to close over the larynx during swallowing, for the evident purpose of keeping food out of the larynx. It will also close promptly on breathing poisonous gases. The larynx, trachea, and lungs of some animal should be studied. Also the movements and forms of the mouth in forming the letters.

No other muscles in the body can be moved with the rapidity and precision of those used in speaking. They are greatly under the control of the will, and can be trained to wonderful feats of singing and

speaking, and ought to be in every one at least trained to reading and talking well.

Questions for Review.

1. What does the blood bring to the tissues?
2. What does it carry away?
3. Which of these come to the blood and which leave it by the lungs?
4. What is the object of respiration?
5. How do the tissues carry on respiration?
6. What is this respiration?
7. What is external respiration?
8. What is the essential part of the breathing apparatus?
9. In what places is the oxygen always found?
10. In what form is the oxygen which is in the water used by fishes?
11. What is the arrangement of the essential parts in the gills of the fish?
12. What in the lungs of a man?
13. Name the respiratory passages in their order.
14. How is the blood brought to these, and to what part does it come?
15. Describe the thorax.
16. Describe the structure of the trachea and air tubes.
17. What are the cilia and their use?
18. Of what does the act of respiration consist?
19. What is the relation of the lungs to the cavity of the thorax?
20. What keeps the lungs expanded?

21. How is inspiration accomplished?

22. Give the action of the muscles employed.

23. How is expiration accomplished?

24. How is the diaphragm pressed up? What is the action of the intercostals?

25. How are the motions of respiration regulated?

26. How do they vary?

27. What of the control of the will?

28. Which respiratory act is each of the following: sighing? crying? laughing? sneezing? coughing?

29. How does the air coming from the lungs differ from that going to the lungs?

30. What of organic substances in expired air?

31. How much air do the lungs contain?

32. How much is thrown out at one expiration?

33. What is the diffusion of gases? Illustrate.

34. How is oxygen brought to the air vesicles?

35. How is carbon dioxide brought out?

36. How does the oxygen get to the tissues?

37. Trace the carbon dioxide from the tissues to the air.

38. What is the use of the red blood corpuscles?

39. What of the necessity of ventilation?

40. How much space should each one have in a working room?

41. How does this apply to your school room? To your sleeping room?

42. If there is not a space to each one, what must be done to counterbalance its lack?

43. What are some of the dangers in the air?

44. How may some of these be avoided?

45. Describe the larynx.
46. How are the vocal sounds produced?
47. What is the epiglottis and what is its use?
48. What are the motions in the larynx?
49. How are the different sounds of the letters produced?

CHAPTER XIII.

THE SKIN AND THE KIDNEYS.

The covering of the body is one of the most important, and at the same time one of the most interesting, organs to study. It has, as we shall see presently, several important uses. The one which is easiest seen is that of protecting the parts below it from mechanical injuries. In this way it acts as a strong suit of clothing—flexible and yielding, yet not easily broken or torn.

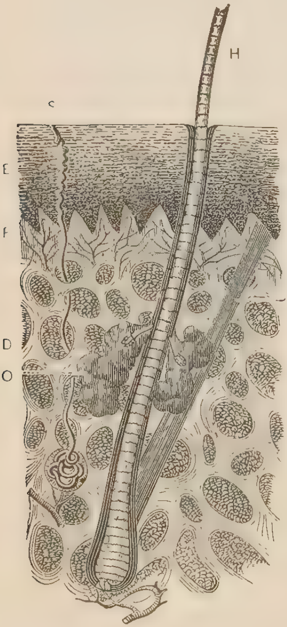

Fig. 42.

SECTION OF THE SKIN. MAGNIFIED.

H, hair; *E*, epidermis; *D*, dermis; *P*, papillæ; *S*, mouth of a sweat gland; *O*, oil gland.

General View.—The skin is of a very complex structure. It consists of two layers, which are so arranged as to support very many different organs. Fig. 42 shows a representation of a section made vertically through the skin, considerably magnified. The whole skin is about one tenth of an inch thick, less in many parts,

being thickest on the palms of the hands and soles of the feet. It is thinnest at the joints and wherever rapid motions are required, as over the eyelids.

Structure of the Skin.—The skin is composed of two layers, as shown in the figure. The outer layer is called the *epidermis*. It forms a thin covering over the dermis. The epidermis has no blood vessels in it, and as to nerves, it has only the smallest nerve fibrils in its lowest parts. It forms a layer that will not let water pass through it either into the body or out from the body. It prevents poisonous substances from passing into the body, and furnishes proper covering for the ends of the nerves of touch and of temperature.

Growth of the Epidermis.—The epidermis grows in its lower layer of cells, which crowd on those that lie above and push them out. The outer layers are constantly wearing away. Thus one's skin is always a comparatively fresh one.

The Dermis.—The lower layer of the skin is the *dermis*. It is composed of a closely woven sheet of connective tissue. In it are placed great numbers of blood vessels, a network of nerves, a network of lymphatic vessels, immense numbers of sweat glands, the sheaths of the roots of hairs, and the oil glands.

When the skin of an animal is made into leather it is mainly the connective tissue of the dermis that is tanned.

The dermis is tied fast to the rest of the body by a layer of connective tissue. It is so fastened that it may be loose enough to be pushed about a little over each point, and at the same time be pretty firmly

held in place over the whole body. The skin is really stronger and tougher than one might suppose from its appearance.

Papillæ.—The upper surface of the dermis is raised into an immense number of small projections called *papillæ*. Fig. 43 shows some from the palm of the hand from which the epidermis has been removed. These are found everywhere in the skin, but are most numerous on the palms of the hands and the soles of the feet.

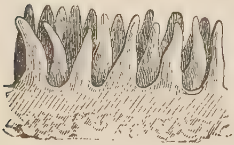

Fig. 43.

PAPILLÆ FROM THE PALM OF HAND, WITH THE EPIDERMIS REMOVED. MAGNIFIED.

The epidermis fits closely over these and so nearly levels up the space between them that their existence would not be known if viewed from this surface.

But on the palms of the hands and soles of the feet the epidermis can be seen to be in fine parallel ridges. These ridges are over rows of papillæ, just beneath in the dermis. The papillæ are shown in both Fig. 42 and Fig. 43. In each papilla is a capillary blood vessel and a network of nerves, and in very many a minute, curiously formed body in which a nerve ends, which may be a nerve of touch or one of temperature.

Fat in the Skin.—In the lower layer of the dermis, in the meshes of the connective tissue, are many little globules of fat. Sometimes the fat may increase to such an extent as to make a thick layer between the skin and the muscles and other parts beneath. When this is the case the body is more rounded in outline.

This layer of fat serves to lessen the effects of blows on the body and helps to keep it warm.

In some of the lower animals, such as seals and whales, this layer is enormously developed, and is known as the blubber of the whale. The large amount of fat found in these animals causes them to be hunted for their oil. This arrangement allows these animals to live in extremely cold climates, and in the case of seals and walruses, to bear the rough contact with rocks and ice which the manner of life of a seal or walrus requires.

The Sweat Glands.—A sweat gland (Fig. 42) is formed of a knot of a coiled tube placed in the lower layer of the dermis. It is connected with the outer surface of the skin by a continuation of its tube through the two layers of the skin.

The coiled part secretes the sweat or perspiration, which, carried to the surface, is poured out, to evaporate completely if it comes out slowly, or to gather into drops if it flows out rapidly.

The secretion of the sweat is regulated by nerve fibers which come to the coiled part. The material of the perspiration, which is mostly water, is furnished by the blood flowing through a network of capillaries inclosing the coiled tube.

Perspiration and the Temperature of the Body.—Each one knows well that rapid running or exercise of any kind, or even very little exercise on a very hot day, will cause the sweat to form in large quantities over the surface of the body.

Now, as this always occurs under these same circumstances, it might be supposed that there is some

reason for the connection of the two occurrences. And such is the case.

Source of Heat in the Body.—Let it be recalled that the increase of motion of the body can occur only by increase of the oxidations. This increase we found always to be accompanied by the production of heat. Increase of activity of any tissue increases the amount of heat in the body. When the digestion is most active it is found that the blood coming away from the digestive organs is warmer than that going to them. Besides the heat produced in connection with the usual activities of the tissues, the body has the power to produce oxidations in some of the tissues for the sole purpose of increasing the heat.

The body is so constructed that it works best at a temperature of 98° Fahr. If it rises above that limit only one or two degrees, it is very much out of its proper condition, and if one or two degrees still higher, life is in great danger. If it fall below 98° it is also in danger.

Regulation of the Temperature of the Body.—Now, special activity in the muscles in vigorous exercise produces heat which would raise the temperature higher than 98° if there were not a way to reduce it by some cooling process. This process is by evaporation of the water of the sweat.

Evaporation is a very effective means of cooling. It requires a large amount of heat to evaporate a small amount of water.

This is shown by placing a moist cloth on the bulb of a thermometer. As the cloth dries, the mercury

shows, by falling several degrees, that *it is cooled.* If some substance like gasoline or ether, which evaporates more quickly, is used, a very low temperature can be produced, although the experiment is carried on in a warm atmosphere.

The sweat glands are all the time sending out water, which generally evaporates as soon as it reaches the surface. When an increase of heat in the body that might bring the temperature of the body above 98° Fahr. occurs, the nerves stimulate the glands to work, and thus to pour out a greater amount of sweat. The amount sent out will be according to what may be needed at that particular time to cool the body sufficiently to overcome the increase in the heat.

This arrangement must act very promptly and very perfectly, as the body will keep the same degree of temperature on going from a cold room to a warm one, or from a cold day to a warm one, or from one season to another.

We may say, then, that one of the most important uses of the sweat glands is to regulate the temperature of the body.

Perspiration as a Secretion.—The sweat is mostly water, but as it passes out it carries a very small amount of salines and a small amount of organic substances. These are regarded as excretions to be cast out of the body.

The Skin as an Organ of Touch and Temperature.—In the skin, as was mentioned, the nerves of sensation end in special organs, which are affected, the one by pressure, the other by change in temperature.

By means of these bodies, the skin becomes an organ with the most important duty of giving the knowledge obtained from these senses. It thus becomes both a constant guard to warn us of all danger, and to give us the information needed at every moment of our existence.

The Hair.—The hairs are really epidermis grown out into long threads. Each one forms on the top of a special papilla. This papilla is very much like any other papilla, except that it is at the bottom of a little pit.

The cap of epidermis (which is formed over it) remains, new portions being formed beneath it, and so on until it becomes a very slender, but in some cases an enormously elongated rod of epidermis.

Minute hairs are scattered all over the body. A little experiment with some of them, say those on the back of the hand, will show that they greatly aid in touch. Each one has a nerve at the bottom of its papilla.

The Nails.—The nails are thick plates of epidermis growing out from a number of papillæ. They grow continually, and thus provide for a comparatively new nail all the time. One may determine the rate of growth by making a line on one and observing the number of days it takes to move a certain distance. The use of the nails is made very plain in attempting to take hold of very small objects.

Uses of the Skin.—We may sum up the most important uses of the skin as follows:

1. It makes a strong suit of clothing to protect the body against mechanical injuries.

2. It prevents the absorption of injurious substances from without.
3. It prevents evaporation, except under control.
4. It helps regulate the temperature of the body.
5. It gives us, through the organs of sense in it, very important and really necessary knowledge.

Hygiene of the Skin.—To accomplish these very important functions to the best advantage, it should be kept clean. When clean it is in the best condition and in the least danger.

Bathing.—Bathing the body often enough to keep it clean is essential to the best health, and is a fundamental requirement of good breeding.

No special directions are necessary to regulate bathing if it be done for the purpose of keeping clean. Each one can decide such matters for himself. The time, place, and amount of water may safely be left to his judgment. The temperature of the water is best at that degree which is comfortable to the bather.

Common sense will teach every one the precautions against taking cold in the act of bathing. The only rule necessary to be emphasized is that the bath come often enough to keep the body clean.

From what has been said of the structure, uses, and needs of the skin, it need hardly be added that the smearing of the skin with any kind of dirt, no matter of what color or price it is, is not to be done in safety to the skin so treated. Fortunately this fashion is no longer practiced by the most refined people.

The Kidneys.—It may be repeated here that from the changes that take place in the body the three principal wastes are:

1st. *Carbon dioxide*, which is got rid of mainly at the lungs;

2d. *Water*, which is principally thrown off at the skin; and

3d. The waste containing nitrogen, a substance something like ammonia, called *urea*, which is thrown off by the kidneys.

The kidneys are placed one on each side of the spinal column in the abdominal cavity, near the last dorsal and the two or three upper lumbar vertebræ. They are large glands, through which a great amount of blood passes. They separate from the blood that goes through them certain substances dissolved in water. The principal one is *urea*.

These substances are removed from the body. Thus the blood in its circuit passes the lungs, where it loses carbon dioxide; the kidneys, where it loses urea, and the skin, where it loses water. If any one of these excretions be stopped, the result will be fatal.

Questions for Review.

1. What use of the skin is the most easily seen?
2. Of what layers is the skin composed?
3. What of its thickness?
4. What are the uses of the epidermis?
5. How does the epidermis accomplish this?
6. Of what is the dermis composed?

7. What organs does it contain?
8. How is it attached to the body?
9. What are the papillæ?
10. Where are they and what of their number?
11. Why do they not show on the surface of the skin?
12. Explain the parallel ridges on the palms of the hands.
13. What does each papilla contain?
14. How is the fat of the skin arranged?
15. What use may the fat serve in this place?
16. What of its development in seals and whales?
17. Describe a sweat gland.
18. What of its action?
19. How is its action regulated?
20. Under what conditions is the secretion of perspiration increased?
21. What is the temperature of the body?
22. What are the sources of heat to the body?
23. What is the effect on the temperature of special activity of the muscles?
24. How is this effect counterbalanced?
25. Show how evaporation is a cooling process.
26. How is this process in the body governed?
27. What of the sweat glands as organs of secretion?
28. How is the skin an organ of special sensation?
29. What is a hair?
30. How is it formed?
31. What are the uses of hairs?
32. What are the nails, and their mode of growth?
33. What are their uses?

34. Give a summary of the uses of the skin.

35. What is the most important point to be considered in the hygiene of the skin?

36. What is said of bathing?

37. Give the position of the kidneys.

38. What are their functions?

39. What are the three important wastes of the body, and where is each thrown out of the body?

40. What of interference with either of these processes?

CHAPTER XIV.

THE NERVOUS SYSTEM.

The Nervous System as a Means of Coördinating the Organs of the Body.—In our first lesson it was noted that in any movement of the body the parts worked together in some sort of harmony. The boy in climbing a tree sees a limb and reaches out his hand for it. In this action the eye and the arm must have some connection. In the whole action the feet, legs, hands, arms, eye, ear, the heart, the lungs, and very many other parts of the body work with each other, and not against each other, in accomplishing this act.

Now, when the muscles of the legs are in greater activity, the heart must beat more vigorously. This could not occur if there were not some means of communication between them. So it is with the hundreds of other examples that might be given. The means of communication in all these cases is the Nervous System. We shall try to see as clearly as possible how this is the case.

Nerves in the Arm.—In studying the motions of the fingers it was observed that nerves pass to each muscle, and that every muscle was made to contract by a nervous stimulus sent into it. What this stimulus is like it would be hard to say.

If the nerves of the arm could be exposed as shown in the figure, and a single nerve be cut, then the will would lose all power to cause the muscles to which the nerve is distributed to contract, and at the same time a touch on the hand could not be felt. Now, if the end of the part of the nerve connected with the muscle should be pinched, the muscle would contract promptly. If the end connected with the brain were pinched, pain would be felt.

Fig. 44.

NERVES OF FORE-ARM.

Nervous Impulses.—This shows that the nerves conduct some kind of energy which, coming into the muscle, makes it contract, but coming into the brain causes a feeling of pain, touch, or other sensation.

What these nervous impulses are like we can not answer. In electricity we have an example of an impulse which metal wires will conduct a long distance. By its means an instrument in one city may be set in motion by a movement in a distant city.

Nervous impulses act in somewhat the same way, yet we think they are not electrical currents. But

we do not understand what electrical currents really are.

The Structure of Nerves.—The larger nerves appear as white cords. These, as they go to be distributed to the various parts of organs, divide and subdivide until they are so small that they can not be seen with the naked eye. The larger cords and all their branches are called nerves.

A Nerve Fiber.—The microscope shows the nerves to be made up of very definite parts. Each one is a bundle of very minute tubes, through the center of which runs a fine core of substance, which is really the conducting part of the nerve. One of these tubes with its central core, which is the *axis cylinder*, is called a *nerve fiber*.

The parts of a nerve fiber are arranged very much as those of an insulated wire of an electrical apparatus. The axis cylinder corresponds to the metal wire, and the parts around this to the wrapping around the wire.

A nerve is like a bundle of these insulated wires made up into a cable, such as is used when a number of wires are to be laid under ground or in the water, or gathered together to occupy less room, as in the telephone cables.

How the Nerve Fibers are Connected.—Each nerve fiber in the nerve runs independently of the rest in the nerve. As the nerves reach the parts of the organs, their fibers separate into smaller and smaller bundles, until finally one single fiber ends in a single part of the tissue to which it goes.

These outward ends are in muscles, glands, the

skin, and, indeed, in all parts of the body. Because of the color of nerve fibers they are said to be composed of "white matter." But it is necessary to remember that the white matter is always composed of these nerve fibers.

The fibers traced toward the axis of the body are found to run to the spinal cord. Some end here, and some pass on through the spinal cord. But when the final ending is reached each fiber is found to end in a substance in the spinal cord and in the brain called the "gray matter."

Structure of the Gray Matter.—It requires the

Fig. 45.

NERVE CELLS.

a, axis cylinder of a nerve.

microscope to see the structure of the gray matter. It shows it to be made up of very great numbers of little bodies of an irregular shape, called *nerve cells*. A nerve cell, Fig. 45, may have many projec-

tions from its surface, but one of these projections continued a long distance makes the axis cylinder—that is, the nerve core of the nerve fiber.

To make this a little clearer, let us imagine that we could take hold of one of the nerve cells in the spinal cord or brain and lift it out without breaking the delicate fiber connected with it, and that we could also unravel it from the nerve until we reach the outer organ to which it goes, which in this case, let us suppose, is a muscle.

Now, let us take out the microscopic bit of muscle to which the fiber is attached. If this could be done and the parts magnified, we should have the arrangement represented in Fig. 46.

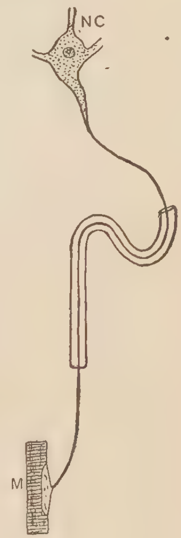

Fig. 46.

Diagram to show the Relation of Nerve Cell (*NC*) to Muscle (*M*) through its Nerve Fiber.

This figure shows well the connection between the nerve fiber and the nerve cell on one side, and the muscle substance on the other. The tube-covering of the axis cylinder is removed part of the way. In one thing the figure is wrong; the length of the fiber is very much greater in most cases than is represented in the figure.

What is the Action of the Nerve Cell?—It is from the nerve cell that the impulse starts which makes the particle of muscle contract. If in this figure (46) we substitute for the muscle some part that is sensitive to touch, light, sound, or some other things which

affect us, the slender nerve fiber would conduct the impulse from this part of the organ to the central nerve cell. Then the nerve cell is stimulated or shocked, we may say. Some nerve cells in the brain or spinal cord receive these shocks by means of their fibers, and others send them out to muscles and glands.

The sensations which we receive are made by the impulses which come to the nerve cells in the brain, and the motions and other forms of activity are caused by the impulses which go from the nerve cells of the brain and spinal cord. It may be said that the functions, in part, of the cells are to *receive impulses*, *change them*, and *send out other impulses.*

Distribution of the Nerve Fibers and Nerve Cells.—The nerves are composed of fibers. The white matter of the brain and spinal cord is also of nerve fibers. The gray matter is composed of nerve cells, with some fibers. It is placed mainly in the core of the spinal cord and over the surface of the brain, and in certain bodies at the base of the brain.

The Divisions of the Nervous System.—The whole nervous system is divided into two great divisions—the *cerebro-spinal* system and the *sympathetic* system.

The Cerebro-spinal System.—A general view of this is shown in Fig. 47. This system consists of the brain and the spinal cord, and the nerves that branch from these—twelve pairs from the brain, and thirty-one pairs from the spinal cord.

The Brain.—The brain is the large portion of the nervous system enclosed in the cranium. The weight

Fig. 47.

General View of the Cerebro-spinal System.

is about three and one fourth pounds. Fig. 48 shows it seen from above; Fig. 49 the same seen from below; and Fig. 50 shows a side view with certain parts cut through vertically.

Of the parts shown in these views the *cerebrum* is the largest and is also the uppermost. It is divided into the right and left hemispheres by a deep ditch, called the longitudinal fissure. Its surface is broken up into many curving ridges, which are called the convolutions. They are shown in Figs. 48, 49, and 50. The part which is like a stem to the cerebrum is the *medulla oblongata*, *MD* in Fig. 50, and 9 in Fig. 49.

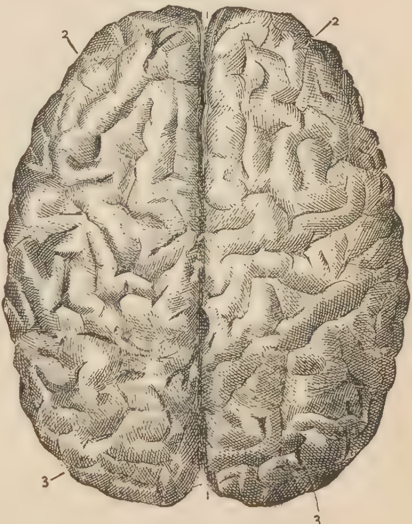

Fig. 48.

Brain seen from Above.

1, longitudinal fissure separating the hemispheres; 2, frontal lobes of the cerebrum; 3, posterior lobes.

The medulla continues down into the spinal column as the spinal cord. In Fig. 50 that portion marked *Sp N*, to which the roots of two nerves are attached, is a part of the spinal cord.

Attached to the back part of the medulla close up

to the cerebrum is the *cerebellum*. This is shown as cut through in Fig. 50, *Cbl*, and at 4 in Fig. 49.

At the base of the cerebrum, near where the medulla joins it, are several parts not shown in the figures, which are sometimes referred to as the ganglia at the base of the brain.

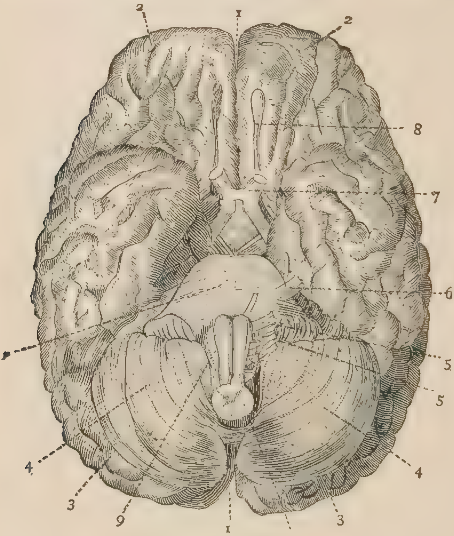

Fig. 49.

BRAIN SEEN FROM BELOW.

1, longitudinal fissure; 2 and 3, front and posterior lobes of the cerebrum; 4, cerebellum; 7, optic nerve; 8, olfactory nerve; 9, medulla.

In Fig. 50 are shown the twelve pairs of cranial nerves, which are often known by the terms first cranial nerve, second, third, etc.

The Spinal Cord.—The spinal cord continues from the medulla, at the opening in the occipital bone, to about the second lumbar vertebra. It is about eighteen inches in length.

The Spinal Nerves.—From the spinal cord thirty-one pairs of nerves pass out to be distributed to the organs of the body. Each of these nerves starts from two roots, an anterior and a posterior root, which

soon join together to make one nerve; but the nerve soon separates into a great number of smaller and

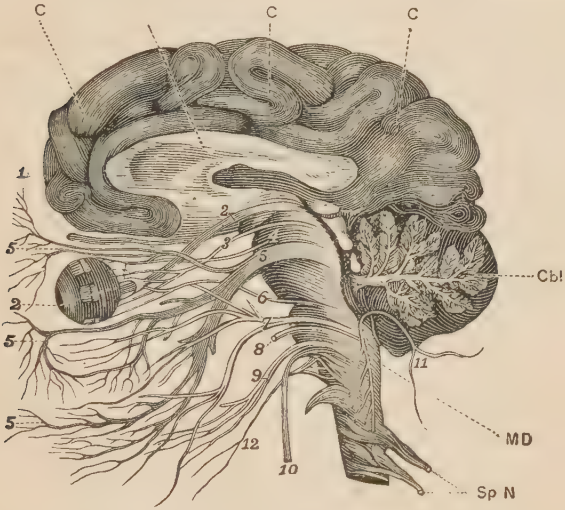

Fig. 50.

BRAIN AND CRANIAL NERVES SEEN PARTLY IN SECTION AND PARTLY IN SIDE VIEW.

C, convolutions of the cerebrum; *Cbl*, cerebellum in section; *MD*, medulla oblongata: *Sp N*, spinal nerves. The numbers indicate the twelve pairs of cranial nerves in their order.

still smaller branches, until, as was seen in a former section, they reach all the smallest parts of each organ.

The Sympathetic System.—This term is applied to that part of the general nervous system which consists of a row of ganglia on each side of the spinal column, and the network of nerves with which it is connected, that run all through the body. The ganglia are connected with each other, and, through

the spinal and cranial nerves, with the spinal cord and the brain. It is really not a separate system, but a part of the general nervous system.

Questions for Review.

1. How is it shown that the nervous system connects distant parts of the body?
2. Give examples of parts of the body working together in harmony.
3. What effects would appear in each case if the cut ends of a nerve of the arm were pinched?
4. What would this prove?
5. What of the nature of the nervous impulses?
6. How are nerves distributed?
7. Of what is a nerve composed?
8. Describe one of its elements.
9. To what may a nerve fiber be compared, and to what a nerve?
10. What is the relation of the nerve fiber to its nerve and to its fellow nerve fibers?
11. How do the fibers end outwardly?
12. What is the white matter?
13. What is the gray matter?
14. How does each fiber end in the central axis of the nervous system?
15. Draw a diagram showing how the nerve fiber is connected outwardly and centrally.
16. What is the function of the nerve fiber?
17. Where is the impulse received?
18. From where is it sent out?

19. In what part of the nervous system are the fibers found?

20. Where are the nerve cells principally located?

21. What are the divisions of the nervous system?

22. Give an outline of the cerebro-spinal system.

23. Where is the brain and what is its size?

24. What are its principal parts?

25. Locate each and give its connections.

26. Describe the cerebrum.

27. Describe the medulla.

28. Describe the cerebellum.

29. What are the ganglia at the base of the brain?

30. What of the cranial nerves?

31. Describe the spinal cord.

32. How many spinal nerves are there?

33. How are they connected with the cord and how distributed?

34. What is the sympathetic system?

35. What are its relations to the cerebro-spinal system?

CHAPTER XV.

THE NERVOUS SYSTEM—(Continued).

Structure of the Spinal Cord.—The spinal cord is about as large around as the little finger. It is really a double cord, the two halves being joined by a narrow portion, but the outside sheath of connective tissue gives it the appearance of being single.

Its central portion is occupied by gray matter—that is, the nerve cells. Outside of these are nerve fibers, making up its white matter. The roots of the spinal nerves are nerve fibers, most of which are connected with the cells in the spinal cord. Many fibers run on up to the brain just outside of the core of nerve cells. The spinal cord is like a large nerve, except that it has gray matter in its central portion, while the nerves do not have nerve cells.

Structure of the Brain.—The *medulla* is really a continuation of the spinal cord, and is very much like it. But toward the upper end the gray matter containing the cells, instead of being simply in the center, becomes broken up into several portions, and the nerve fibers are scattered among them.

In the cerebellum the gray part with the nerve cells is mainly on the surface, which is greatly increased by being much folded. The white fibers in it run from the medulla, in the center of these folds,

to reach the cells of the surface. When the cerebellum is cut through, the arrangement of the gray and white portions has the appearance shown in Fig. 50.

In the cerebrum the surface of the convolutions is covered with a layer of gray matter (nerve cells). These convolutions greatly increase the amount of surface. At the bottom of the cerebrum are several masses of gray matter called the ganglia at the base of the brain. Some nerve fibers from the medulla pass to the nerve cells of these ganglia; others pass to the nerve cells of the convolutions.

Nerve fibers in the cerebrum also run in many other directions—some to connect cells of one hemisphere with those of another, or one part of one hemisphere with those of another part of the same hemisphere. All these fibers constitute the white matter of the brain.

Fig. 51.

SPINAL CORD.

A General View.—When one studies a large city, one thing that impresses him is the immense number of wires that run in every direction. They seem to be in utter confusion through their great numbers and the many courses they take. If the wires are traced they will all be found to issue from several points in large groups; these are the telephone stations and telegraph offices.

Some of the wires connect these stations with each

other; others go to rooms in separate houses all over the city and surrounding country.

Messages are continually arriving at the central stations, and are continually going out from them again, and by this means an immense amount of business is carried on, including movements of railroad trains, so that they will not collide, the meeting at a special time and place of thousands of people engaged in thousands of transactions which require the most perfect working together of the people at a considerable distance from each other, moved by a knowledge of facts still more scattered and from more distant sources.

To such a system of communication in the city and its surrounding country could the nervous system in the body be compared. If in the city there were no other means of communication except through the wires and the central offices, and if to accomplish this a wire went to every room in the whole city and country, the comparison would be a closer one.

Nerve fibers pass by means of nerves to the spinal cord from every small portion of each tissue of the body, except from the upper parts of the thin epidermis, but even there the nerves lie so closely under it as to be affected by pressure on it.

In the spinal cord some of the fibers are connected with the nerve cells in the center, which form a series of central offices connected with each other by many fibers. Other fibers pass up the cord to the brain, where they make a most intricate maze, some connected with cells of one nerve mass, or nerve center.

as it is called; some to another. These centers correspond also to central offices.

In the body some of the fibers are connected with parts from which messages can be sent in but by which they can not be received. They are the sensory fibers. Others are so connected that messages are only sent out; they are the motor fibers. The nerve cells in the centers both receive these messages and send them out.

Messages are constantly pouring into the central offices, and constantly others are being sent out over the hundreds of thousands of fibers. The result is seen in the various forms of activity of the body, which occur in just the right way to correspond to the necessities of the body at every minute.

Thus the nervous system, by impulses received, changed, and sent out, like that of the system of telegraph and telephone, is enabled to make very many separate parts to work in harmony, some at great distances from the others. This process is called coördination; and it may be said that one great function of the nervous system is that of coördination.

Action of the Nerve Centers.—We may now consider how the nerve centers act and how it is that just the right nerve centers will act at the right time and place, and with the proper strength. All the motions of the muscles and the secretions of the glands are caused by stimuli sent to them from the nerve centers through the nerves.

We have seen in the study of the muscles that motions may be voluntary or involuntary, as they

are called into action by the will or without its influence.

A very large number of motions are involuntary, and any muscle, whether voluntary or not, may be made to move without the action of the will.

When a nerve center sends out impulses which produce what we term voluntary motions, it has been stirred to action in some way by the will. When it sends out impulses which produce involuntary motions, it must have some other source from which it receives its stimuli.

alive

Voluntary Nerve Centers.—By studying the effects of injuries to certain parts of the brain and spinal cord, which have occurred either by accident or disease in man, or which have been made on lower animals for the purpose of experiment, it has been decided that all voluntary motions proceed first from some part of the cerebrum. In the cerebrum, in all probability, the primary sources are in some part of the convolutions. We have seen that the gray matter in the convolutions is connected by fibers with each of the centers below, in the medulla, the cerebellum, and in the spinal cord.

In a voluntary movement of the hand we may picture to ourselves the events that occur, as follows:

The will, in a way which we do not at all understand, causes certain nerve centers in the surface of the cerebrum to discharge their impulses; these impulses go to certain groups of nerve cells in the base of the brain; these, from the action of these stimuli, discharge impulses along their fibers into the group

of cells in the spinal cord which control the muscles that move the hand.

The method may be compared to that used in an army. If the general commanding the whole army desires certain movements in the army, he issues his orders to the group of subordinate officers next to him; they in turn give commands to other groups of officers subordinate to them, who at last give the orders to the men, who execute them in performing the movements desired by the general.

Functions of the Cerebrum.—It has just been shown that one of the functions of the cerebrum is that of causing the voluntary movements. It has also been proved that it is only when the nervous impulses reach the cerebrum that any kind of sensation is produced, such as seeing, hearing, and feeling of any kind. It is only when the cerebrum is in a healthy, uninjured condition that the memory, judgment, or emotions, such as love, fear, hope, and the like, are possible. The cerebrum seems to be necessary in producing consciousness and is the source of every form of mental activity.

Reflex Actions.—The spinal cord is able to produce motions when entirely independent of the brain. Every one has seen a chicken jumping about and flapping its wings violently after its head has been taken off. In the headless body it is the spinal cord that is sending out the impulses that cause the violent motions seen. By very careful study of the action of the spinal cord in animals whose brains have been removed, and in man when by accident the spinal cord has been severed from its connection

with the brain, it has been found that the spinal cord never acts except on impulses coming to it from outside sources.

In the case of the jumping of the headless chicken, every motion is caused first by a touch on the outside of the body, which starts impulses that reach the nerve cells in the spinal cord. These stimuli cause the nerve cells to send out stimuli which cause motions. It acts just as it is acted upon. This sort of action is called *reflex action*, and such a nerve center is termed a *reflex center*.

Functions of the Spinal Cord and the Medulla.—The gray matter of the spinal cord and the medulla, which may be considered as two parts of the same thing, is mainly made up of reflex centers. The cord and the medulla may be said to have chiefly two functions: that of the conduction of the nervous impulses between the brain and the rest of the body, and that of reflex action.

Examples of Reflex Actions.—If the finger is touched with a hot object it is suddenly jerked away. This will occur even when the owner of the finger is asleep, or so busily engaged in thinking of something else that he does not at first notice what is happening. The motion is accomplished by the spinal cord stirred to action by the impulses from the heated nerve ending in the skin.

The question might be asked, *How is it that just the right muscles act to pull the hand away?* The answer is that, as the whole arrangement is for the purpose of taking care of the hand in such cases, the nerves of the skin of the hand are made to

connect directly with the nerve center which controls the muscles of the hand, and not those which control other parts.

All along the spinal cord are reflex nerve centers, which act for other parts as this center does for the hand. Very many of the motions in walking, in running, in the movements of the arm and hand, and in the movements of the trunk, are really reflex actions of the spinal cord.

In the medulla are the centers which produce the motions of a cough, when impulses come from something irritating the lining of the throat; a sneeze, when the nasal passages are stimulated; a deep breath, when water is dashed on the body; the involuntary act of swallowing, when the food has reached the œsophagus; and very many other necessary actions.

Reflex Action of other Centers.—While the reflex actions of the medulla and the spinal cord are very numerous, and include the great majority of motions, either in being their sole cause or in influencing them to a greater or less extent, yet at times all the other nerve centers serve as reflex centers.

Many movements which are at first caused by an effort of the will accompanied by the closest attention may, on sufficient repetition, come to be accomplished by reflex action. For example, if one should have to begin again to learn to walk, every movement of the feet and legs, and every movement of the arms and body in balancing the body over the legs, would have to receive attention and effort for their production.

But with one who has learned to walk well these motions are guided by the sensations which come to the nerve centers from sensations of sight of the path, from feeling it with the feet, and from many sources, so that walking may be accomplished when one's mind is wholly occupied with other matters. Indeed, it is sometimes accomplished during sleep, when there seems to be complete unconsciousness.

Uses of Reflex Action.—If the pupil will now put his body under close observation for a single day, and make a list of actions which are purely reflex actions, or partly so, he can better see how much a day's life of action is accomplished by reflex centers, and how important they are. It would be impossible for one to carry on the necessary motions of the body for even a very short time by voluntary action.

If only the comparatively few processes that have been mentioned in this little book be recalled, such as those that regulate the beating of the heart, the movements of respiration, the secretions of the many glands, the movements in digestion, besides those just mentioned in walking, in controlling the hand, in speaking, and if to these be added a thousand others, then the force of the truth stated above of the importance of reflex action may be seen.

Functions of the Cerebellum.—The cerebellum, no doubt, possesses functions which have not yet been discovered. Its size would lead us to suppose that it is of considerable importance, while, up to the present time, not a great amount is definitely known of its functions.

It appears to be connected with the power of making voluntary motions work together and in harmony; for example, in such a motion as making the thumb strike any one of the fingers, or, in walking, the keeping one foot back while the other is brought forward. This function is described as that of *coördinating voluntary movements.*

Blood Supply to Nervous System.—The nervous system is well supplied with blood, the largest part, the brain, having large arteries going to it. Its tissues are very sensitive to any changes in the character or amount of the supply of the blood. A lack of oxygen in the blood quickly shows itself in its effects on the brain. If the lack be great, fainting and loss of consciousness is the immediate result, and if continued but a short time, death will be sure to follow.

Poisons in the blood affect the brain very quickly. One of the most noted of these is the poison *alcohol.* In a few minutes it deranges the action of the nerve centers in a powerful manner, with often the most terrible results. Its continued use never fails to impair all the functions of the nervous system, involving as well the mental and moral nature of the individual.

The nervous system requires the rest found in sleep. Loss of sleep, if carried to an extreme, is a very dangerous experiment. Of all the parts of the body, none make so strong a demand for good air, good food, free from poisonous substances, and sufficient rest, as do the highly organized tissues of the nervous system.

The Effect of Alcohol on the Nervous System.—(For a fuller discussion of effects of alcohol, see pp. 185–192.)

There is no part of the body on which alcohol has so marked an effect as on the nervous system. When taken into the stomach it is soon absorbed and circulated through the body, and its effect on the central nervous system (brain and spinal cord) is immediate. Even a small amount of alcohol disturbs the action of the brain. This is seen in the false judgments directly following its use. The person may feel warmer when it can be shown that he really is no warmer. He says the drink has produced an exhilarating effect on him. This simply shows that the alcohol has so affected his brain that he cannot judge correctly even about his own bodily state.

In the next stage he gets very happy or angry about almost nothing, or he becomes silly where, in his normal state, he would be much in earnest. All these feelings are the result of a disordered condition of his nervous system. He is deceived, and he cannot adapt himself to his conditions. If he should be in such a state a considerable time, he could not escape making great mistakes in his conduct. A man thus deliberately makes himself a less intelligent being. He disturbs those functions which we regard as the highest, and which we are accustomed to look upon with pride as the chief characteristics by which we are distinguished from the lower animals.

If greater amounts of alcohol are used, all these symptoms are intensified until there may be a complete overthrow of the reason and a loss of voluntary

control over the body. The sense impressions may be wholly misinterpreted. Such excessive use of alcohol, if long continued, will so profoundly disturb the action of the brain, that the patient may be attacked with such diseases as *delirium tremens* or *insanity*, whose final outcome, after much misery, is death.

The moderate but long-continued use of alcohol has not the same effect on all people. In some it may cause little apparent injury, while in others it will in time produce changes in the structure of the brain. These changes are similar in character to those which occur in the kidneys, the liver, and the heart; that is, there is a greater development of the connective tissues at the expense of the nervous elements of the brain. The effect, however, is more injurious on the body, as a whole, when the central nervous system becomes deranged, for through it all the other organs are more seriously affected.

Questions for Review.

1. Describe the structure of the spinal cord.
2. How is it like a nerve, and how is it different?
3. How are the nerve cells and nerve fibers arranged in the medulla?
4. What is the arrangement of the cerebellum?
5. How are the nerve cells of the cerebrum distributed?
6. How are the nerve fibers of the same arranged?
7. In what ways may the nervous system be likened to a telegraph or a telephone system in a city?

8. What things are accomplished by the telephone system?

9. What things are accomplished by the nervous system?

10. What is meant by coördination?

11. Give examples illustrating its use in the body.

12. Explain how one of the functions of the nervous system may be considered to be that of coördination.

13. What is the cause of every action of either a muscle or gland?

14. What are voluntary and involuntary actions?

15. At what place do the voluntary impulses originate?

16. What is the evidence that such is the case?

17. Describe the course of these impulses from their origin to the muscles that move the hand.

18. How may the action of the nerve centers be compared to the methods in the movement of an army?

19. What are the functions of the cerebrum?

20. What of motions produced by the spinal cord when not connected with the brain?

21. Give examples of such cases.

22. What is found to be necessary to cause the spinal cord to thus act?

23. What is reflex action?

24. What are the functions of the medulla and spinal cord?

25. Give as many examples as you can of reflex action, and state in each case what causes the stimulus to go to the nerve center, and the part moved.

26. How is it that just the right motion is produced in each case by the outer stimulus?

27. What other centers may act as reflex centers?

28. Give examples of such actions.

29. How may an act which is voluntary become reflex?

30. What proportion of the actions of the body are reflex?

31. Of what advantages are the reflex centers?

32. Give many examples of such advantages.

33. What of the functions of the cerebellum?

34. Illustrate how it is supposed to act.

35. What of the blood supply to the nervous system?

36. What is the effect of a lack of oxygen?

37. What of the presence of poisons in the blood?

38. What of the use of alcohol?

39. What of sleep?

CHAPTER XVI.

SENSATIONS.

Definition.—By the term sensations is meant the impressions or feelings which are made upon our minds by the things outside of our bodies, or by changes within our bodies. For example, a bright light gives us one kind of an impression, a vibrating tuning-fork another, an odor still another. Or, we may have sensations from changes within the body, as a feeling of thirst or of fatigue.

It is through parts of the body which give us these impressions or feelings that we gain our knowledge of things outside of us, or of the state of our own bodies.

Special and General Sensations.—If one considers the various sensations he has, and will compare them with each other, he will see that they differ very much in the definiteness with which they can be located in the body. When one feels tired, it is hard to say just where the feeling is located. Even after one has become tired from continued action of the arms, the feeling of fatigue can not be located in any particular part of the arms, nor does it seem to be confined to the arms alone.

It is very different when we receive a sensation from an object touching the finger. In this case it can be determined just where the point is that is

touched, and the idea gained by the sensation is more definite and distinct.

The last sort of a sensation is called a special sensation, while those like that of fatigue are known as general sensations.

Sense Organs.—The special sensations are those of *sight*, *hearing*, *smell*, *taste*, *touch*, and *temperature*. Each of these has a special kind of apparatus with which the sensation is produced. In each case it consists of, *first*, an outer part which is so formed that it can be affected by some peculiar kind of energy, the perception of which energy, as something different from any thing else, leads us to call the organ a special-sense organ. Besides this outer part there is, *second*, the sensory nerve; and a *third* part, the nerve center in the brain.

General Sensations.—In the production of general sensations there are also the inner parts, the nerve centers, and the sensory nerves, and there may be special outer nerve endings. But how they appear and where they are located is not known. The general sensations are numerous, and many of them hard even to describe. Among them are *pain*, *hunger*, *thirst*, *nausea*, and *fatigue*.

Pain.—Any one of the sensory nerves, whether of the special or general sensations, seems to be able to give rise to the sensation of pain if stimulated with too great energy. Thus, light, sound, things that touch the skin, or that affect nerves connected with any part of the body—in fact, which either give rise to a pleasurable sensation or to no feeling at all, and thus are only known by the reflex actions which

they produce—may cause intense pain if the stimulus be increased beyond a certain degree.

The Use of Pain.—A means of producing *pain* is of the greatest importance to the body. It is simply the way in which the nervous system calls attention in the most emphatic manner to the fact that something is wrong.

Pain even does more than call attention to the wrong. It drives us to right the wrong, to get rid of the pain. We are sometimes rather slow to do what is right, even when our attention is called to it. We must have a stronger stimulus to action. Pain furnishes us that stimulus. Pain is graded all the way from simply being an unpleasant feeling up to the most intense suffering. To avoid the latter it is certainly well to pay attention to the former.

Hunger and *thirst* are forms of sensations which arise from a diminished supply of food and water to the tissues. They are produced through parts of the nervous system not definitely known. These, together with the feeling of having had enough when sufficient food and drink have been taken, are of the utmost importance in regulating the supply of both.

Above all, we should attempt to preserve the healthy action of these sensations, since, when they are not abused or abnormally developed, they furnish us with the very best guides in the extremely important process of taking food and drink. With these disturbed, the preservation of the general health is almost impossible.

The Sense of Touch.—This sensation is produced by pressure on the epidermis, also on the mu-

cous lining of the mouth and in the beginning of the nasal passages. The special organs of touch are microscopic bodies of a peculiar form placed in the papillæ, or just underneath the epidermis. The nerves of touch end in these bodies, and when pressure is brought to bear on the epidermis it starts impulses in the nerves which, coming to the brain, give the sensation of touch.

These organs are unequally distributed in different parts of the skin, being much greater in number in the palms of the hands, the lips, and tongue, and in the soles of the feet, than in other parts of the body. The little hairs scattered over the body, which have at their roots branches of sensory nerves, greatly aid in determining the pressure of any thing against the skin.

Different parts of the skin differ very much in the accuracy with which they report about the things touched. It is only by the palms of the hands, bottoms of the feet and toes, tips of the fingers, and by the lips and tongue that the shapes of things can be made out when touch alone is used.

Other parts of the body, such as the skin on the forehead, can determine the presence of a lesser pressure than can the fingers and the palms of the hands. It would be profitable for the pupil to experiment in these particulars with different parts of the surface of the body.

The Sense of Temperature.—This is the sense by which we determine the differences of the temperature of objects. Its outer organs are in the skin, in the lining of the mouth, pharynx, and œsophagus. These outer parts of the sense organ of temperature

are mingled in many places with those of touch, but the two have been clearly proved to be distinct sensations and must have different nerves.

One may, by employing a warm or a cold rod, explore the surface of the skin and determine what parts are most and what are least sensitive to heat and cold.

The uses of the senses of touch and temperature are very obvious. We may say for them that they are not the least important of the senses. The sense of touch seems to be possessed to a greater or less degree of definiteness by all animals.

The Sense of Taste.—The nerves of taste end in little bodies in the mucous covering of the tongue, and in the soft palate. This sense determines certain properties of liquids. The forms of the sensation of taste have been stated to be included in the four following: *bitter*, *sweet*, *saline*, and *sour*.

The little bodies in which the nerves of taste end are placed in some of the papillæ in the parts named, and are only affected when the substances are dissolved. In this the saliva is of great aid.

We are accustomed to think that we taste many things which we know only by the sense of smell. This is the case with flavors, like that of vanilla, of onion, of garlic, and with the flavors of different kinds of meats.

Our opinion in this regard is only an example of how we often make use of things a long time without stopping to determine accurately any thing about them. By carefully keeping the odors of such substances that have flavors out of the nostrils their so-called flavors can not be tasted.

The Sense of Smell.—The fibers of the nerve of smell end in little cells imbedded in the mucous membrane of the higher parts of the nasal passages. These cells come to the very surface, where their extremities are kept moist by mucus. They are affected by vapors and gases.

A very great number of odors can be distinguished by the organ of smell. Its sensitiveness is remarkable when it is considered what small quantities of substances can fill a large room with odors which can be detected by the sense of smell, although but a very small part of the air containing the odor can reach the olfactory surface of the nose.

The Uses of Taste and Smell.—The chief uses of these senses are plainly to examine both the food taken and the air breathed, and both organs are located admirably for these purposes.

Questions for Review.

1. What are sensations?
2. Illustrate this by examples.
3. What of the difference in the definiteness of the sensations received?
4. Illustrate this by examples.
5. Define a special sensation.
6. What is a general sensation?
7. What are the special senses?
8. What are the parts of the sense organ?
9. In what do the organs for general sensations differ from those for special sensations?
10. Name some of the general sensations.

11. How is pain produced?
12. What are the uses of pain?
13. Give examples.
14. How are hunger and thirst caused?
15. What are their uses?
16. What produces the sense of touch?
17. Where are the endings of the nerves of touch?
18. How are the touch organs distributed?
19. What function have the small hairs scattered over the body?
20. Where can points touched be most definitely located? Where can shapes of objects be best made out?
21. What parts of the skin are most sensitive to pressure only?
22. What is the sense of temperature?
23. Where are the outer parts of the organ distributed?
24. How may the sensitiveness of different parts of the skin to touch and temperature be determined?
25. What are the uses of each of these senses?
26. How do the nerve fibers of taste end?
27. What are the properties that the sense of taste determines?
28. How does the saliva aid the sense of taste?
29. What are flavors?
30. Where are the endings of the nerve fibers of smell?
31. What of the sensitiveness of the sense of smell?
32. What is the use of the sense of taste?
33. What are the uses of the sense of smell?

CHAPTER XVII.

SIGHT AND HEARING.

The Organ of Sight.—In the organ of sight, just as in the other sense organs, there is a part that is sensitive to a particular stimulus, which is connected by nerve fibers with a nerve center in the brain.

In the eye the part that is affected by the light, the *retina*, is in the back of the eyeball, its exact position to be made out presently. The nerve is the optic or second cranial nerve. The remaining parts of the eye are all helps in bringing the light on the portions sensitive to it.

External Parts of the Eye.—We may begin our study of the eye by observing what is exposed to view in our own or in our companion's eye. First we have the curtain, the *eyelids*, fringed by the eyelashes. Just back of the eyelids is the front part of the ball of the eye.

This looks like glass. Its shining appearance is due to its being very smooth and continually washed over by the secretion of tears. This secretion is rubbed over the eye by the act of winking, which is kept up incessantly.

As the tears pass over the eye they flow away and are gathered up by two tiny openings in the inner

corner of the eye. These openings lead to the *tear ducts* (*lachrymal ducts*). The ducts, after passing through the lachrymal bones, empty upon the inner surface of the nostrils.

The very front of the eyeball is transparent, and when viewed from one side is seen to protrude slightly from the rest of the surface. This is the *cornea.* Beyond the edges of the cornea comes the white of the eye.

Looking through the cornea we see the colored part called the *iris.* It has a round black spot in the center known as the *pupil.*

The pupil is only a round hole in the iris. It is black, as is a hole in any closed box, because there is very little light inside to come out.

Fitting closely over the visible front part of the eyeball is a very thin layer of skin called the *conjunctiva.* It runs from the eyeball to the under side of the lids, at whose edges it becomes continuous with the skin of the outer surface of the lid.

The conjunctiva is well supplied with nerves, which give a sensation of great pain on the presence of any foreign body on the surface of the eye or under the lid.

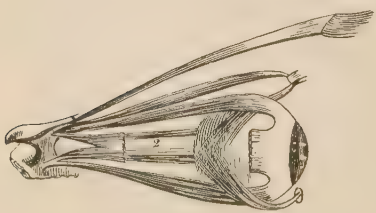

Fig. 52.

THE EYEBALL WITH ITS MUSCLES.

The Eyeball.—The ball of the eye is a globe of about one inch in diameter. It rests in a bony socket, in which it can be turned in every direction by its

muscles. Between the eyeball and the walls of the socket is a padding, principally of fat and connective tissue. The eye is held in place very firmly, as one will find when he attempts to remove the eyeball from the head of some animal for study.

Fig. 52 shows the eyeball with its muscles attached. The upper muscle not attached to the ball belongs to the upper eyelid. The muscle in front is cut away

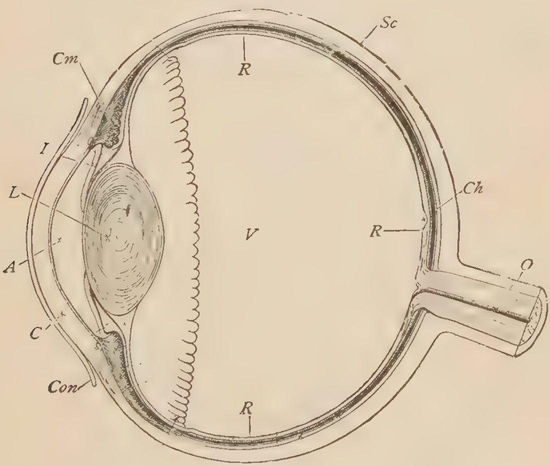

Fig. 53.

SECTION OF THE EYEBALL.

Con, conjunctiva; *C*, cornea; *A*, aqueous humor; *I*, iris; *L*, crystalline lens; *V*, vitreous humor; *Sc*, sclerotic coat; *Ch*, choroid coat; *R*, retina; *O*, optic nerve; *Cm*, ciliary muscle.

to show the optic nerve just back of it. The ball and optic nerve are also shown in Fig. 52 at 2.

The Walls of the Eye.—The eye may be considered as a globular box. The outer walls consist

of three layers or coats. Fig. 53 is a section of an eye which well shows these parts. The front part consists of the transparent cornea, continuing as the white of the eye, which is called the *sclerotic coat* (*Sc*). This at the back extends over the optic nerve as its sheath.

This covering is of very tough connective tissue, and is the main part of the wall of the box, supporting the other parts and furnishing places for the attachment of muscles, as seen in Fig. 52.

Just inside of this coat lies the *choroid coat* (*Ch* in Fig. 53). It is dark in color and closely filled with blood vessels. Toward the front part of the eye it contains the muscular fibers (*Cm*) of the ciliary muscle. Farther forward it is continued into the *iris*, marked (*I*). Just inside the choroid is the very thin transparent *retina* (*R*). It is continuous with the optic nerve (*O*).

The walls are held out firmly in their spherical shape by the contents of the globe, which are the *vitreous humor* (*V*), the *crystalline lens* (*L*), and the *aqueous humor* (*A*). The vitreous humor looks like a very transparent jelly; the lens is firmer, and when fresh has the appearance of a clear convex lens of glass, while the aqueous humor consists of but a few drops of a liquid that is mostly water. The lens is held in place by a sheath of a kind of connective tissue.

Seeing.—As was stated above, it is a part of the retina that is affected by light. It is that part which lies against the choroid coat. The retina, although exceedingly thin, is a very complex structure. While the description of its microscopic parts

may be omitted, it may be stated that the fibers of the optic nerve pass to the front of the retina, where they spread over the whole retina. The end of each fiber, however, turns toward the choroid coat, and, through different parts of the retina, becomes connected with each one of the vast numbers of minute bodies in the retina known as the *rods* and *cones*, whose ends point toward the choroid coat.

The light affects these rods and cones, and they start the stimulus, which, traveling along the optic nerve to the nerve center in the brain, produces the sensation.

Distinct Vision.—Perception of the exact outlines of an object can only occur when a definite image of the object is formed on the rod and cone layer of the retina. Every one knows that an image of a lamp flame or of the window can be formed on a sheet of white paper by the use of a convex lens.

The photographer uses a convex lens also to form an image in the camera. In the eye, the cornea and the crystalline lens are the convex lenses which form the image on the rods and cones.

The iris, by narrowing or enlarging the pupil, which actions it accomplishes by circular and longitudinal muscular fibers in its substance, regulates the amount of light, and thus helps to make the image more distinct.

Accommodation of the Eye to Different Distances.—If, while you keep your eyes fixed on the words of this page, you give attention to some object beyond the book, the farther object will be found to be indistinct. If now you look at the object beyond,

the words of the book are indistinct. The reason for this is that a lens can not make on a screen definite images of objects at different distances at the same time. If the lenses and the retina of the eye were to remain just exactly the same in shape and distance from each other, we could never see any thing in definite outline except at one certain definite distance.

The eye is enabled to accommodate itself to objects at different distances by changing the amount of curvature of the crystalline lens. This is done by the action of the ciliary muscle, *Cm*, in conjunction with other parts. The lens becomes more curved for a near object, and less so for distant objects—that is, objects more than twenty feet away.

Short-sightedness.—A normal eye can accommodate itself, as has just been shown, to both near and distant objects. In a near-sighted eye, generally on account of the too great length of the eyeball, the lens can not make the image of distant objects fall on the rods and cones, and even near objects must be brought close to the eye to be seen clearly. Concave glasses will correct this defect.

In Long-sightedness the eyeball is commonly too short, and thus prevents images of near objects from being formed at the proper place. Convex glasses are used to correct this defect.

There are many other defects which eyes may possess, which can not be explained here. As most of them are such in nature that they grow worse in time and may prove serious, it is always best, when any are suspected, to have the eye examined by one skillful in such matters.

Sensation of Hearing.—An object producing a sound, such as a violin string, does so by vibrating very rapidly—that is, it swings backward and forward with great rapidity. These vibrations give their motions to the wood of the body of the violin; and this in turn sets the air to vibrating. Every little particle of air is swinging to and fro with the same rate as the vibrating body.

The sensations of hearing are produced by these vibrations being transmitted by parts of the hearing apparatus to the little bodies in the innermost part of the ear in which the auditory nerve fibers end.

The Auditory Apparatus is very complicated, and our description will include but a brief outline. The apparatus is generally considered in three divisions: the *external* ear, the *middle* ear, and the *internal* ear.

The *external ear* includes the visible projection called the *pinna*, and the tube that leads from it, known as the *external auditory canal*, which, at its inner end, is closed by a membrane called the *membrana tympani*, which separates it from the middle ear.

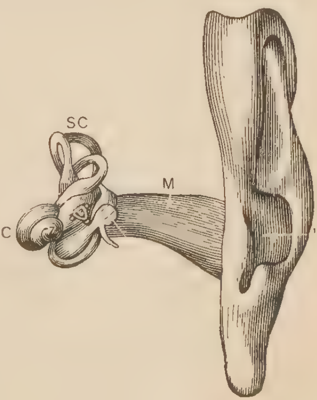

Fig. 54.

The Auditory Apparatus with the Surrounding Bone removed.

M, external auditory canal; *SC*, semicircular canals; *C*, cochlea.

The *middle ear* is a small cavity in the temporal bone, lined by a thin

mucous membrane. It opens into the pharynx by the *Eustachian tube*. It is separated from the external canal by the membrana tympani. A series of three small bones, the *malleus*, the *incus*, and the *stapes*, fastened together and attached to the sides of the cavity, connects the membrana tympani with a membrane between the middle and the internal ear. The middle ear contains air, which comes into it through the Eustachian tube.

The *internal ear* consists of very small tubes of membrane, which lie in corresponding tubes of bony channels in the temporal bone. Both inside and outside of these tubes of membrane is a liquid which is mainly water. The three divisions of the internal ear are the *semi-circular canals*, the *vestibule*, and the *cochlea*. The auditory nerve fibers end in cells on certain parts of the internal lining of these membranous tubes.

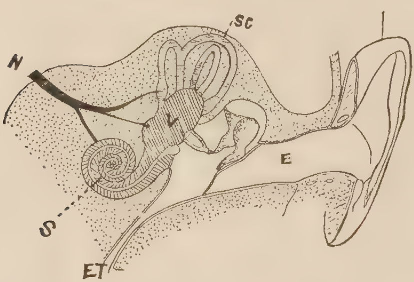

Fig. 55.

A DIAGRAM OF A SECTION OF THE AUDITORY APPARATUS.

E, external canal: *M*, in the middle ear, where is the chain of bones; *V*, vestibule; *SC*, semi-circular canals; *N*, auditory nerve; *S*, cochlea; *ET*, Eustachian tube.

The functions of some of these parts are not definitely known, but it is believed that the sensation of sound is produced by the stimuli to the nerve endings in the internal parts of the cochlea. The cochlea consists of three tubes wound around in the

shape of a snail shell. The nerve fibers end in the walls of the middle tube.

General View of the Action of the Auditory Apparatus.—The motions of the vibrating body set the air into vibrations; the vibrating air causes the membrana tympani to swing to and fro with the same rate; these swings are communicated by the series of bones to the membrane to which the stapes is attached. The motions of this membrane set the liquid of the internal ear in motion, and this acts on parts that set in motion the bodies in which the auditory fibers end. The motions start this stimulus, which causes the sensation of hearing.

Questions for Review.

1. What are the parts of the eye immediately concerned in seeing?
2. How are the remaining parts of the eye to be regarded?
3. Describe the eyelids, and give their use.
4. What is the use of the tears?
5. Describe the cornea.
6. Describe the iris.
7. What is the pupil?
8. What is the conjunctiva, and what is its use?
9. Describe the eyeball.
10. How is it held in place, and how moved?
11. Describe the arrangement of the coats of the eye.
12. What are the humors of the eye, and what are their functions?

13. Describe the crystalline lens.

14. How is vision produced?

15. Where are the rods and cones, and what is their use?

16. What is necessary for perception of exact outlines?

17. How is this provided for in the eye?

18. What are the actions of the iris, and for what purpose?

19. How is the eye accommodated to objects at different distances?

20. What is a long-sighted and what a short-sighted eye?

21. How is each of these defects provided for?

22. What is the cause of these defects?

23. How are sounds produced?

24. How is the sensation of hearing produced?

25. What are the general divisions of the ear?

26. Describe the external ear.

27. Describe the middle ear, giving also the arrangement of the bones and their connection.

28. Describe the internal ear.

29. Where do the auditory nerve fibers end?

30. Give a general statement of the action of the auditory apparatus.

CHAPTER XVIII.

ALCOHOL, TEA, COFFEE, TOBACCO, OPIUM.

In certain chapters throughout this book we have called attention to the effects of alcohol on the special organs there described. It seems desirable now to speak of the effects, on the body as a whole, of alcohol, as well as of tea, coffee, tobacco, and opium. It is on the body as a whole that the most injurious work of these agents is to be seen. These substances are so widely used, and the consequences of their excessive use are so serious, that a special chapter may well be devoted to a discussion of their effects in the hope that many may be deterred from the formation of these dangerous habits.

Description of Alcohol.—Alcohol in a pure state is a transparent liquid. It is somewhat lighter than water. It is so nearly a true liquid that it forms no lasting bubbles when shaken up in a bottle. It burns with a pale blue flame, without smoke, thus producing a great amount of heat. Pure alcohol is known as "absolute alcohol." Alcohol mixes readily with water in all proportions. The alcohol usually sold, known as "commercial alcohol," generally contains five per cent or more of water.

Source of Alcohol.—Alcohol is formed by the growth of the yeast plant in solutions containing

sugar. When yeast is placed in a solution containing sugar of the right proportions, and it is kept in a warm place, the yeast grows rapidly, and in its growth converts the sugar into alcohol and carbonic acid. The carbonic acid, being a gas, generally bubbles up through the solution and escapes; but the alcohol, being a liquid, remains dissolved in the solution.

In making bread, however, the carbonic acid resulting from the growing yeast is held by the sticky dough, which it lifts up and makes "light." In the process of baking, both the carbonic acid and the alcohol are driven off.

The juices of ripe fruits contain sugar. If these juices are left exposed so that the minute yeast plants in the air can get into them, they undergo a process called "fermentation." This process of fermentation is the growth of the yeast plants, and, as just explained, it produces carbonic acid, which mainly escapes from the juice and leaves the alcohol remaining in the liquid. Thus the juice of grapes is changed into wine, the juice of apples into cider. If the juices, after the formation of alcohol in them, are allowed to stand exposed to the air, other minute organisms grow in them, which will change the alcohol to acetic acid. Wine and cider are thus changed to vinegar. Many other solutions of sugar are used to allow the formation of alcohol, and thus many forms of alcoholic drinks are produced.

Beer, ale, and porter belong to the group of malt liquors. In making these, barley is kept moist and warm till it begins to sprout. In the act of sprout-

ing, the starch of the grain is changed to sugar. The sprouted grain is dried and ground up, and water is added, which dissolves the sugar and other substances of the grain. To this solution yeast is then added, which converts the sugar into alcohol and carbonic acid. The resulting clear liquid containing the alcohol separated from the undissolved parts constitutes beer, ale, or porter, the distinctions between these being due to certain differences of treatment in the manufacture of the liquids.

Another class of alcoholic drinks is produced by first allowing alcoholic fermentation by yeast to take place, and then separating the liquor by distillation from the other matters in the mixture. Examples of such drinks are whisky, brandy, rum, and gin. These contain a far greater amount of alcohol than the wines or beer.

The quantity of alcohol in the different drinks varies greatly. In some kinds of beer the amount is as low as two per cent, while in some forms of brandy it reaches fifty-five per cent. In all alcoholic drinks, however much they differ in flavor, the alcohol is of the same nature, and has the same origin. The different flavors by which the various alcoholic drinks are distinguished are due mainly to substances extracted from the materials used in their manufacture. The most characteristic effects resulting from the use of alcoholic drinks are due to the alcohol contained in them.

Physiological Action of Alcohol.—In considering the physiological effects of alcohol, there are certain facts which must be kept in mind.

First, there is the great difficulty of determining the *exact* effect, on any special organ, of any substance taken as food, medicine, or poison. We can usually say that a certain food is good or bad because, when it is used constantly, the general health of the body is improved or impaired. But it would in most cases be impossible to tell the special effect of that food on the various tissues. Of course, in all such cases there are people ready to advance theories to explain the exact action of the various foods on each of the tissues. But explanations which have not been experimentally proved are of no value. There are many medicines whose general tendencies are pretty clearly known, but whose special effects on the cells of any tissue are wholly unknown. Quinine is a good example. It is well known that if given in a proper way it will, in a great number of cases, cure certain diseases; but it is impossible to say definitely how the cure is effected, and it certainly is not possible to show with microscopic sections any changes in the tissues produced by such small quantities of quinine.

Some of the most active poisons, while they show, by causing death, their sure and speedy effect on the body as a whole, give no indication, under the most careful examination, of their special action on the various tissues of the body.

There is no doubt that when any substance, as a food, a medicine, or a poison, produces an effect on the body, it does so by causing certain changes in the cells of some or all of the tissues. But what these changes are, it is usually impossible to determine.

A second fact that should be kept in mind in considering this subject is that individuals vary greatly in the way they are affected by different kinds of foods and drugs. Often it is found that a food which seems beneficial or harmless to most people may produce in certain individuals unpleasant or distressing symptoms. A drug which may powerfully affect a majority of people may be used by a few without marked injurious results. Even the effects that generally follow the use of any drug vary greatly in character and degree in different persons. Hence we must not draw any definite conclusions from a single experience or from a few observations on a few individuals.

A third fact important to remember is this: The effects of substances may vary under different conditions; as, in various degrees of health; in connection with different kinds of diet; in activity or rest of the body; in different climates; and in different ages. In view of these facts, the following statements of the physiological effects of alcohol must of necessity be of a general character, and they cannot be made applicable to each individual case.

If a small amount of alcohol is taken, it may produce no perceptible effect except a slight increase of the pulse rate.

The effects of large amounts of alcohol are well summed up by Dr. Emerson, as follows:

"If large doses be given a healthy person, the usual course is, first, a flushing of the face, with a greater flow of words and ideas, and tendency of muscular activity; then imperfect articulation, loss

of judgment, unsteady gait, dulled moral sense, irregular eyesight, loss of sensation, then of consciousness, and, finally, even impaired (vegetative functions) breathing and circulation—all of these phenomena being successive paralyses of nervous centers of the brain, medulla, and spinal cord.

"If large doses be often repeated, the alcohol carried through the various organs modifies their nutrition and the growth of the mere connecting tissues (framework) at the expense of their more important special tissues. Thus the stomach and liver, kidneys, and, finally, even the voluntary muscles, and the all-important involuntary muscle called the heart, degenerate. These processes are slow and only result from the decided abuse of alcohol, especially spirits."

The student is referred to the chapters on circulation (p. 77), foods (p. 96), and the nervous system (p. 162), for a description of the special effects on these organs of the use of alcohol. But to understand the full action of alcohol on the body as a whole, we must remember that the results described for these various organs occur all together. These organs, as we have learned, have very important functions. When the action of one is interfered with, its effect is felt on the whole body, and thus the direct injury occasioned by alcohol is heightened. If the functions of these important organs are being interfered with, the general health of the body is sure to be undermined. The capability of the body for accomplishing physical or mental work is greatly lessened. Its power of resisting the attacks of disease is decreased. Its power of recovery when dis-

ease has invaded the system becomes much weakened. This condition of the body is sometimes described as "an undermined constitution" or "a lowered vitality." While it is hard to describe accurately what has occurred to the body, the condition is none the less real. It can be easily recognized, and is indeed a serious matter.

If the body sustains accidental injury, or for some cause a surgical operation is to be performed, the surgeon realizes that recovery is likely to be less speedy, or less sure, if the patient has been accustomed to the use of alcoholic drinks.

Under training for any athletic contest, experience has shown that the greatest success cannot be secured when alcoholic drinks are indulged in; consequently their use is forbidden. In cases where long-continued, severe bodily exertion is necessary, or an unusual amount of exposure to fatigue, cold, or heat, experience has also shown that the drinking of alcohol is detrimental. In these cases the objection to the use of alcohol is clear. Still the effects are the same whether we are engaged in a severe contest or not. We are all the time in some sort of contest, and certainly each one wishes to be at his best. Experience shows clearly that we are not at our best after using alcohol. The same may be said of the use of tea, coffee, and opium and its compounds.

Alcohol as a Medicine.—The discussion of the question in regard to whether alcohol may be beneficial in the treatment of disease is out of place here. When we are sick we should be put under the care

of a well-trained physician. Then we must trust to his learning and skill, and follow his directions. The forms, conditions, degrees, and courses of diseases are so varied, and so obscure, that it would generally be dangerous to trust ourselves to any one not trained or skilled in the practice of medicine. There are many poisons and other injurious substances that may be used with great benefit in certain conditions or phases of disease. Physicians differ in opinion as to whether alcohol is one of them. But, in any case, the problem must be solved by the physicians, and, however settled, it will not affect the question of the effect of alcohol on the healthy body.

Other Substances in Alcoholic Drinks. — Thus far we have spoken only of the alcohol in alcoholic drinks, but they contain a number of other substances. Some of these occur naturally, and others are added either to change the flavor or as adulterations. Some of these are known to be injurious and others to be harmless. The number of these substances is so great that a special treatment of each is impossible here.

Intoxication. — Thus far we have mainly dwelt on the effects of long-continued use of alcohol on the general health of the body. There is, however, one result which is so evident that neither physiologist nor physician is needed to detect it or to point out its evils; that is, the intoxicating effect of alcohol taken in large doses. This is known in common language as getting drunk. The evils of drunkenness are so great and so well known that we need not dwell on them here. Fortunately, a large number of

those who use alcoholic drinks do not become habitual drunkards. However, it is of the greatest importance that the fact be emphasized that the moderate use may become immoderate. It is only from the ranks of the moderate users that the great army of drunkards is recruited. It is impossible for a man to foretell, when forming the habit of drinking, whether or not he will be able to control himself from running into excess. Hence when a man cultivates this habit he runs this risk.

It would seem as if no person who has contemplated the terrible things which have been done under intoxication would voluntarily assume a habit which involved even the bare possibility of such an end. Indeed, all such arguments against the use of alcohol as those contained in the facts of its effect on the heart, the kidneys, or the liver, or on the general health, pale before the undisputed evidence that by means of alcohol an intelligent man may act without reason; that a kind-hearted man may become brutal to his most loved friends; that an honorable man may become dishonorable; that a man with a noble nature may acquire the most depraved tastes; that its use has over and over again been the cause of bitter disappointments, of intense sufferings, and of crime.

Effects of Alcoholic Drinking on the Community.—It has been shown beyond any doubt, by repeated study of statistics gathered from prisons, insane asylums, and almshouses, that the use of alcoholic drinks is the most frequent cause of crime, insanity, and poverty. These facts are so well known,

and have been before us so long, that they do not impress the general community in proportion to their enormity. If some new form of drug or food, or some new political or social movement, were introduced which, in a year after its introduction, would bring about in the civilized world physical and moral results as great as those produced by alcohol, the fact would stir every class up to arms. There would be a universal, energetic, and immediate movement towards its suppression.

Most other poisons so affect their victims that they alone suffer the consequences of their use. But alcohol renders its slaves active agents in bringing suffering and degradation on others in the community. Other vices are the usual associates of drunkenness.

The evil influences of most drinking places and of many drinking customs are well known and undisputed. Thus alcohol comes to affect not individuals alone, but the moral tone of the community as a whole. In these facts, again, we are forcibly shown that arguments against the use of alcohol based on moral grounds far outweigh all those drawn from physiological considerations.

Tea and Coffee. Tea consists of the dried leaves of a plant extensively cultivated in China, Japan, Ceylon, and India. The leaves contain a number of vegetable substances common to all leaves, but in addition they contain an alkaloid known as *theine* which is characteristic of tea leaves. There is also a large amount of *tannin*.

Coffee consists of the seeds or so-called "berries" of a plant which is cultivated for drinking purposes.

The berries are roasted, and by this means an *aromatic substance* is developed which gives coffee its peculiar flavor. Besides this aromatic substance there are, of course, many other ingredients in the berries, prominent among which are *tannin*, certain *vegetable acids*, and *caffeine*.

Theine and Caffeine.—It is to these substances that the characteristic physiological effects of tea and coffee are due. Theine and caffeine are exactly alike in their chemical composition, and the same physiological effects have been assigned to both. In tea there is a greater amount of tannin. This has an injurious action on the digestive processes.

After speaking of the beneficial effects of a moderate use of tea for some persons, Dr. Yeo says:

"On the other hand, it is quite certain that tea taken in excess, and in some constitutions, may become very injurious. It will not infrequently excite and maintain most troublesome gastric catarrh, the only remedy for which is an entire abstinence from tea for a considerable period. It is often also the cause of troublesome cardiac palpitations, together with muscular tremors and general nervous agitation. We have noticed that tea will often commence somewhat suddenly to disagree with a person, and excite dyspeptic symptoms, coincidently with the occurrence of nervous worry, and that after the cause of the nervous worry has passed away tea may again be taken, in moderation, with impunity. In irritable states of the stomach tea is also apt to disagree, especially if the coarser teas containing much tannin are taken; these when taken in large quanti-

ties during, or too soon after, a meal, will disturb and often seriously hinder the digestive processes."

The beneficial effects which are thought to belong to the moderate use of tea and coffee are no doubt often more apparent than real; they produce an agreeable feeling, which makes the user believe that he is benefited when perhaps only a harmful change has taken place.

If no other harm came from the use of these substances than the constant deception as to the true state of the body, even that would be considerable damage. For, if the proper appetite is interfered with, it is quite certain that at times too much or too little food will be taken. Tea and coffee have also the power of relieving the sense of fatigue, and while they may thus be valuable aids as a temporary relief from suffering, they become very harmful if they lead us to overlook and disregard the cause of the weariness. Fatigue itself has its uses, and we would sooner or later suffer if deprived of its warning voice. In other words, the delicate balance of coordination between the processes of nutrition and necessities of the various organs would be lost. Such a state continued could not result otherwise than injuriously, the extent of injury depending on the degree to which the organism was affected. The claim that tea or coffee will enable the body to do more work on a smaller amount of food is absurd. Energy cannot come from nothing. As the source of energy in the body is oxidation of oxidizable substances (foods), it is impossible for a substance to cause work to be done by doing away with its source of energy.

Whatever makes us "feel better" when we really are not better, forces our nervous system to tell lies to us. This "feeling better" is also followed by "feeling worse," which is also a lie. These waves of feeling caused by stimulants destroy the unity and effectiveness of life. The greater the wave of exaltation, the lower is the depression which follows. This depression finds its extreme in discouragement, pessimism, and delirium tremens. The user of stimulants leads in a sense a double life, and no form of "double life" can be an effective one.

It is unwise to use even in so-called moderation these stimuli which thus distort the natural action of the nervous mechanisms regulating the nutritive processes. But it is worse than folly to indulge in them to an excess which brings on one the most serious results. Between moderation and excess the gradation is very gradual. Moderation in the great majority of cases becomes a greater or less degree of excess. It is certainly the part of wisdom to forego the passing pleasure that these beverages may give, and avoid the risk of the more lasting suffering or disability which their use may entail.

Tobacco.—Tobacco, as is well known, consists of the leaves of a plant which is raised in many warm countries. It is used in the form of snuff, or is chewed, or smoked as cigars, cigarettes, or in a pipe. It was introduced into Europe at the time of Queen Elizabeth by Sir Walter Raleigh, who learned its qualities from the Indians of North America. From this time its use gradually spread throughout the civilized world.

Among the many substances in the leaves of the tobacco plant the most characteristic is *nicotine*. This is oily and aromatic. It is distilled from the leaves by the heat of the burning tobacco. The vapor of this oil is partly condensed in the cigar or cigarette, or in the bottom of the bowl or along the stem of a pipe; but part of it passes on to the throat and lungs of the smoker.

From these regions it gets into the body. Nicotine is an active poison, even in small quantities. The amount that usually gets into the body by the user of tobacco is very small, otherwise the results would be fatal. As it is, many persons use tobacco for many years, apparently without bad effects. The body, which at first is greatly shocked at the introduction of the poison, seems later to adapt itself to its presence. Still to a great number of persons it is always a poison, more or less undermining the health, or even breaking it down entirely; used in excess—and there is constantly this danger—the results are most serious. The physiological effects of tobacco are as follows:

It affects the heart, and excessive use may produce palpitation and weakening of that organ; it interferes with the digestion and causes a loss of appetite. A long series of carefully conducted experiments shows that immediately after smoking there is a marked loss of the power of doing work with the voluntary muscles. Tobacco is also said to interfere with the development of the red blood corpuscles, whose great importance has been shown in another place.

Of the other substances besides the nicotine which are vaporized by the heat of the burning tobacco, and pass with the smoke into the mouth, throat, and lungs, some produce irritation of the mucous lining and may bring about a diseased state of those organs, such as a chronic sore throat, and other affections. It is thought that many cases of cancer of the mouth can be traced to the habit of smoking. It is agreed on all sides that the use of tobacco is very injurious to the young, and should be avoided by them in every form. There have been many cases recorded of death of young boys through nicotine poisoning from excess in smoking.

The evil effects of tobacco come on in such an insidious way, that very often the sufferer has no hint of the true cause of his troubles; this renders it all the more a dangerous enemy.

The tobacco habit grows on a person till it becomes, in the great majority of cases, a somewhat tyrannical master, demanding great sacrifices of time, health, and money to satisfy its desires. This itself is a form of disease. There is another point of view we should consider. How will it affect our associates? Both smoking and chewing are offensive to most people who do not use tobacco. We should indeed hesitate before forming a habit which will render our close presence disagreeable to many, if not to most of our friends.

Opium.—The use of opium or some of its compounds may become a habit impossible to control. When this is the case the result is usually a most disastrous one. Opium occurs in various forms.

Morphine is a substance made from it. Some compound of opium is found in many medicines, such as paregoric and laudanum. Many of the so-called "cough mixtures" and "soothing syrups" contain some form of it. It is a very dangerous drug. A small amount of it will produce death. In the hands of the doctor it becomes, in disease, one of the most important medicines; but, on account of the danger in its use, it should only be given under direction of a physician. The frequent use of medicines containing opium or its compounds may lead to the formation of the opium habit.

General Considerations in Regard to Stimulants.—The body, as we have seen, is a combination of delicately balanced mechanisms. Through the nervous system many of them are self-regulating. These work most correctly when the stimuli which direct their action come from the actual condition of the body. Thus the movements of respiration are controlled by the amount of carbonic acid in the blood. The beat of the heart is regulated by nervous impulses arising from actual conditions of various parts of the body. We have shown that the actions of the glands, and of other organs, are regulated in a similar manner. Now, if any artificial stimulus acts on these mechanisms, they no longer work in just the manner they should, to be in harmony with the remainder of the system. The body is then not in its best condition.

By means of the nervous system we have sensations which tell us of the outside world through the special senses, and of the state of our own body

through such sensations as those of hunger, thirst, fatigue, pain, etc. Furthermore, we have the power of coming to conclusions in regard to our actions on receiving impressions through these sensations. The whole is a very complex means by which we adapt our actions to conditions in which we are placed.

For the greatest success, for the clearest seeing, for the most efficient action, it is of the utmost importance that correct reports come in for the judgment to act upon. In other words, we wish to know the world as it really is, and we wish to know the actual conditions of the body. This is impossible when the sensations are modified by stimulants. They make us feel warm, cool, hungry, thirsty, well, or ill, when we are not really in such condition. We have reporters about us which tell false reports; hence when we act on those reports our conduct cannot be right.

In the close competition we are sure to meet with in any pursuit in life, the degree of success will depend upon our equipment. How great, then, is the importance of keeping in good condition the delicate mechanisms upon the true working of which depend our chances of success and our capability for happiness! How unwise is the person who voluntarily does anything that may prove a hindrance to the best action of his mind or body!

INDEX.

The explanation of all the words in the index may be found by reference to them in the text.

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Friend;—

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